Infeasibility Analysis for MIP

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A mathematician is a device
for turning coffee into theorems.

Paul Erdős

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Chapter 1

Introduction

All men make mistakes,
but only wise men learn from their mistakes.

Winston Churchill

In the last decades, *mixed integer programming* (MIP) has become one of the essential paradigms used in business and industry decision making. The general framework of mixed integer programming has been successfully applied to many real-world applications like chip design verification, scheduling, supply chain management, and gas transport optimization, to mention only a few. The field's theoretical progress directly stimulated the development of powerful commercial and non-commercial MIP solvers. A lot of progress has been made in the performance of general MIP solver software; problems that seemed out of scope a decade ago can often be solved in seconds nowadays (Bixby et al., 2000; Lodi, 2010; Achterberg and Wunderling, 2013). At the same time, the size of the optimization problems in industry solved by mixed integer programming techniques increased drastically. Nowadays, supply chain management problems with several thousands of operations, customers, and locations and a planning horizon of a whole year with a daily discretization are not uncommon and pose new challenges for modern MIP solvers.

The main task of a MIP solver is twofold. On the one hand, feasible solutions should be constructed fast, especially when solving large-scale and challenging MIPs in practice. On the other hand, the MIP solver should prove either the optimality of a feasible solution or that the MIP is infeasible, i.e., no feasible solution exists.[1] Proving optimality can be generalized to proving that no solution better than a given one exists. One of the central components of modern MIP solvers is the branch-and-

[1] In this thesis, we omit the special case of an unbounded MIP because it is less relevant in practice.

bound algorithm (Land and Doig, 1960; Dakin, 1965). It is a partitioning scheme which recursively splits the problem into subproblems. The MIP solver needs to prove within the branch-and-bound procedure that all not-yet processed subproblems are infeasible when applying the additional restriction that all solutions should be better than the currently best-known solution. Thus, proving infeasibility during the branch-and-bound is a necessary byproduct of proving optimality. Branch-and-bound follows a divide-and-conquer approach and is among the two most important ingredients of a MIP solver (Achterberg and Wunderling, 2013). The relevance of analyzing infeasibilities during the branch-and-bound procedure is shown by the fact that every modern MIP solver tries to "learn" from infeasible subproblems. In the remainder of this thesis, we will refer to any kind of learning from infeasible subproblems as *conflict analysis*.

First ideas of "learning" from infeasible subproblems were suggested by, e.g., Stallman and Sussman (1977), Ginsberg (1993), and Jiang et al. (1994) in the context of *artificial intelligence* (AI) and *constraint programming* (CP). In 1999, Marques-Silva and Sakallah suggested a new search algorithm featuring a powerful conflict graph analysis procedure, which has become one of the central working horses for solving satisfiability problems (SAT). A few years later, Davey et al. (2002), Sandholm and Shields (2006), and Achterberg (2007b) independently suggested integrations of these techniques into MIP.

With his successful adaptation of SAT inspired *conflict graph analysis* for MIP into the general framework of SCIP, Achterberg (2007a) has laid the foundation of conflict graph analysis as it is considered in this thesis. For almost ten years, no follow-up work on the conflict generation procedure itself has been published, to the best of our knowledge. However, for MIP some authors such as Berthold et al. (2010), Dickerson and Sandholm (2013), and Nieuwenhuis (2014) built upon this established technology and applied conflict graph analysis for particular purposes. Berthold et al. proposed a hybrid MIP/CP approach where a fast CP-like search is performed before the branch-and-bound process to collect information about the problem including conflicts, Dickerson and Sandholm proposed a random sampling approach of infeasible variable assignments from which conflict graph analysis can be seeded, and Nieuwenhuis generalized conflict-driven clause-learning as it is known from SAT solvers to integer programming.

Independent of the purely combinatorial approach of conflict graph analysis, a second approach to conflict analysis has emerged more recently. This approach is purely analytic and is based on infeasible *linear programming* (LP) relaxations. It is an analytic procedure called *dual proof analysis* and goes back to the Lemma of Farkas (1902). Interestingly, although commercial MIP solvers such as GUROBI and SAS apply dual proof analysis, it is only mentioned in conference talks (e.g., Pólik, 2015a,b; Achterberg, 2016). In other words, there was no big scientific focus on this topic so far,

although infeasibility is detected frequently during the solving process of MIPs and proving infeasibility is one of the major tasks within the branch-and-bound procedure.

Another observation – and this is the beginning of the story this thesis tells – is that until recently, the major commercial and non-commercial MIP solvers could be partitioned into two groups: Solvers implementing conflict graph analysis (e.g., FICO Xpress and SCIP) and solvers implementing dual proof analysis (e.g., Gurobi and SAS). No solver was implementing and using both techniques simultaneously. During the research activities discussed in this thesis, SCIP evolved to a MIP solver implementing and using both conflict graph analysis and dual proof analysis simultaneously. Moreover, motivated by the results presented in this thesis, FICO Xpress successfully started using a similar approach of combining conflict graph analysis and dual proof analysis.

The goal of this thesis is threefold. Firstly, we will bring conflict graph analysis and dual proof analysis together, investigate differences and similarities, and demonstrate that a general-purpose MIP solver such as SCIP benefits from implementing both techniques and using them simultaneously. Secondly, we demonstrate that conflict analysis is much more than a procedure applied to a byproduct of the search. This thesis enhances existing methods and develops new methods that explicitly aim to generate and exploit additional conflict information. Moreover, this thesis demonstrates that it is worthwhile to learn from parts of the search tree that are close to being infeasible. In other words, "learning" from not-yet infeasible subproblems is beneficial. Thirdly, we advance conflict analysis to general *mixed integer nonlinear programming* (MINLP). Almost all components of a MIP solver, e.g., domain propagation algorithms and primal heuristics, have been successfully adapted and enhanced to improve the solution process of MINLPs. However, the analysis of infeasible subproblems for MINLPs has not been studied before.

Contributions and Structure of this Thesis

In Chapter 2, we introduce and recapitulate general concepts of (computational) MIP, which are frequently used in the remainder of this thesis. Moreover, we give an overview of the state-of-the-art with respect to conflict analysis in MIP and its origin in SAT. Chapters 3 through 7 of this thesis present novel research divided into five strongly connected chapters. In Chapter 8, we conclude and discuss open questions and potential directions of research.

In Chapter 3, we bring the purely combinatorial procedure of conflict graph analysis and its analytic counterpart dual proof analysis together. To do so, we extend the

conflict analysis routine of SCIP to apply both conflict graph analysis and dual proof analysis simultaneously. Moreover, we present a pool-based approach to maintaining constraints derived from conflict analysis and three enhancements of dual proof analysis:

- The strengthening of dual proof constraints by applying single constraint reductions and an update mechanism such that the main property of proving local infeasibility is preserved.
- The generation of alternative infeasibility proofs by applying the c-MIR procedure.
- A new filtering mechanism that takes the density and the amount of generated dual proof constraints into account.

This chapter concludes with an exhaustive computational study demonstrating that SCIP benefits from simultaneously using conflict graph analysis and dual proof analysis.

Our computational study demonstrates that the simultaneous use of both techniques speeds up the search by 5 % to 9 % on instances of varying hardness compared to using any of the techniques individually within SCIP. As a consequence of these research results, the simultaneous approach is used by default in SCIP version 4.0 and higher. Moreover, FICO Xpress started using a similar approach of combining conflict graph analysis and dual proof analysis.

In Chapter 4, we generalize conflict analysis such that it is not restricted to only infeasible subproblems. In this chapter, we focus on two extensions the particular case of infeasibility incorporating the cutoff bound, i.e., the case that the subproblem does not contain a better solution than the incumbent. A *conflict-free dual proof* can be constructed from every feasible LP relaxation. The constructed conflict-free dual proof is not-yet active because it does not prove infeasibility of the LP relaxation it was derived from. This proof might still be sufficient to prove infeasibility within the subtree rooted at the subproblem where the conflict-free dual proof was derived. For example, after an additional bound change, e.g., by branching or propagation, the conflict-free dual proof might be violated, and resolving the LP becomes unnecessary. Therefore, we introduce a pool of conflict-free dual proofs and an update routine to strengthen all conflict-free dual proofs whenever the incumbent improves. As soon as the incumbent solution has improved enough, the maintained conflict-free dual proofs become of interest to be considered in the remainder of the search. In other words, if the new incumbent solution would have been known earlier, conflict analysis could have been applied to the subproblem where the conflict-free dual proof was derived. As a special case, we introduce *solution learning*, where we apply both conflict graph analysis and dual proof analysis to feasible LP relaxations providing an improving integer feasible

solution. Our computational study shows that learning from integer feasible LP solutions and conflict-free dual proofs improves the average performance in terms of solving time by 2 % to 7 % on mixed binary instances of varying hardness.

In Chapter 5, we present a generalization of Rapid Learning, a hybrid MIP/CP approach, first introduced by Berthold et al. (2010). In this chapter, we pick up conflict graph analysis as described in Chapter 3. In contrast to the literature, the presented enhancement of Rapid Learning considers general integer problems instead of pure binary problems. Since Rapid Learning comes with a substantial computational overhead, the original publication suggested applying it at the root node only. To benefit from this powerful hybrid of MIP and CP during the whole solving process, we developed six different criteria to decide when and where to run Rapid Learning at local search tree nodes. All criteria aim to identify infeasible or dual degenerate (sub)problems as early as possible. With these criteria, we can demonstrate that applying Rapid Learning locally within the main search tree improves the overall performance in terms of running time by 7 % to 14 % on integer programming instances of varying hardness.

In Chapter 6, we discuss two new approaches how conflict analysis and primal heuristics can benefit from each other within a MIP solver. In this chapter, we address the following two questions:

- How can the generation of additional conflict information and the construction of improving solutions be combined within a diving heuristic?
- How can primal heuristics benefit from exploiting conflict information?

To answer these questions, we developed two diving heuristics: Farkas Diving and Conflict Diving. Farkas Diving aims to construct dual proof constraints (see Chapter 3) quickly. It chooses variables and branching directions such that it dives towards a valid Farkas system. We show that this strategy is equivalent to an overly optimistic search strategy.

On the other hand, Conflict Diving exploits already learned conflict information to better guide of the search. The main benefit of conflict diving is that it exploits conflict information that is not static during the solving procedure. Older conflict constraints may age out and may be replaced by newer conflict constraints. In contrast, the state-of-the-art diving heuristic coefficient diving solely relies on static variable information derived from model constraints.

This chapter concludes with an in-depth computational study investigating the impact of every component of the newly developed diving heuristics. The computational results show that Farkas Diving and Conflict Diving improve the performance of

SCIP in terms of solving time by 4 % to 16 % on instances of varying hardness. As a consequence of this research, SCIP is shipped since version 6.0 with both FARKAS DIVING and CONFLICT DIVING (replacing COEFFICIENT DIVING) enabled in the default settings.

In Chapter 7, we go two steps further and we consider general mixed integer nonlinear programs (MINLPs). When solving nonconvex MINLPs, local cuts might be added during the solving process to linearize nonconvexities. In the first part of this chapter, we discuss an extension of LP-based dual proof analysis to incorporate local cuts when solving nonconvex MINLPs. Usually, local cuts are ignored during conflict analysis in the state-of-the-art. Consequently, the derived "conflict" is only based on globally valid constraints and might not prove infeasibility anymore. Moreover, it is hardly possible to say when or whether the "conflict" will prove infeasibility. The newly developed technique is called *local dual proofs*. Here, the whole portfolio of dual proof analysis described in the context of mixed integer linear programming and the previous chapters of this thesis can be applied. Our computational study demonstrates that local dual proofs leads to a 3 % to 13 % improvement in terms of solving time on nonconvex MINLPs of varying hardness.

In the second part of this chapter, we show how the theory of dual infeasibility proofs derived from LP relaxations can be applied to convex NLP relaxations. This results in nonlinear dual proof constraints derived from Lagrangian multipliers. To investigate the impact of nonlinear dual proof analysis, we extended the general-purpose MINLP solver SCIP by a fully-fledged NLP-based branch-and-bound procedure. The chapter concludes with a thorough computational study showing that our nonlinear dual proof analysis reduces the solving time of the NLP-based branch-and-bound approach by 42 % to 47 % on MINLP instances of varying hardness.

Publications

Significant parts of this thesis have been published in refereed conference proceedings and international journals. These include the following:

- Chapter 3 is based on Witzig et al. (2017) and Witzig et al. (2021). Both publications are joint work with Timo Berthold[2] and Stefan Heinz[3]. The first publication has been published in the proceedings of *Integration of AI and OR Techniques in Constraint Programming*. The second publication has been published in *Mathematical Programming Computation*.

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- Chapter 4 is based on Witzig and Berthold (2020). This publication is joint work with Timo Berthold and has been published in the proceedings of *Integration of AI and OR Techniques in Constraint Programming*.
- Chapter 5 is based on Berthold et al. (2019). This publication is joint work with Timo Berthold and Peter J. Stuckey[4] and has been published in the proceedings of *Integration of AI and OR Techniques in Constraint Programming*.
- Chapter 6 is based on Witzig and Gleixner (2020). This publication is joint work with Ambros Gleixner[5] and has been published in *INFORMS Journal on Computing*.
- Chapter 7 is based on Witzig et al. (2019) and Berthold and Witzig (2021). The first publication is joint work with Timo Berthold and Stefan Heinz and has been published in the proceedings of *Integration of AI and OR Techniques in Constraint Programming*. The second publication is joint work with Timo Berthold and has been published in *INFORMS Journal on Computing*.

Awards

The publications on which Chapter 7 of this thesis is based have been honored with the following awards.

2021 **Meritorious Paper Award**
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Conflict Analysis for MINLP

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A Status Report on Conflict Analysis in Mixed Integer Nonlinear Programming

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Chapter 2

Concepts

This chapter introduces the main concepts needed in the remainder of this thesis. Most notably, this comprises the class of problems that we are investigating, mixed integer (non)linear programs, and the algorithm by which they are solved, the branch-and-bound procedure. Moreover, we discuss the individual ingredients that belong to a state-of-the-art MIP solver. Here, we will especially focus on conflict analysis and primal heuristics, the two parts of a MIP solver this thesis deals with.

2.1 Mixed Integer Programming

A *mixed integer program* (MIP) is an optimization problem of form

$$c^\star_{MIP} := \min \{c^\mathsf{T} x \mid Ax \geq b,\ \ell \leq x \leq u,\ x_j \in \mathbb{Z}\ \forall j \in \mathcal{I}\}, \tag{2.1}$$

that is minimizing a linear *objective function* $c^\mathsf{T} x$ with respect to a feasible region. Every feasible solution has to satisfy the constraint matrix $Ax \geq b$ with $A \in \mathbb{R}^{m \times n}$ with constraint right-hand side $b \in \mathbb{R}^m$. Moreover, the variable vector $x \in \mathbb{R}^n$ is bounded by a lower and upper bound $\ell, u \in \overline{\mathbb{R}}^n$, where $\overline{\mathbb{R}} := \mathbb{R} \cup \{\pm\infty\}$. We assume without loss of generality that $\ell \leq u$. Formally speaking, every feasible solution has to satisfy $\ell \leq x \leq u$. Furthermore, let $\mathcal{N} = \{1, \ldots, n\}$ be the index set of all variables, and let $\mathcal{I} \subseteq \mathcal{N}$ be the set of variables that are required to be integral in every feasible solution.

In case of $\mathcal{I} = \mathcal{N}$, i.e., all variables have to be integral in every feasible solution, we are talking about an *integer program* (IP). An IP where all variables are bounded by $\ell = 0$ and $u = 1$ is called *binary program* (BP). Moreover, a MIP where for all variables x_j with $j \in \mathcal{I}$ it holds $\ell_j = 0$ and $u_j = 1$ is called *mixed binary program* (MBP). If $\mathcal{I} = \emptyset$ an optimization problem of form (2.1) is called *linear program* (LP).

The literature also contains formulations that maximize the objective function, use "$\{\leq, =\}$"-constraints or assume $x \geq 0$. All these formulations are equivalent and can be transformed one into another (Bertsimas and Tsitsiklis, 1997). For example, when transforming a minimization into a maximization problem the objective function has to be multiplied by -1. The same holds when transforming "$\geq$"- into "$\leq$"-constraints. For a detailed introduction into MIP we refer to Wolsey (1998) and Wolsey and Nemhauser (1999).

Solving MIPs is known to be $\mathcal{NP}$-hard (Karp, 1972). Consequently, no polynomial-time algorithm exists for general MIP under the assumption that $\mathcal{P} \neq \mathcal{NP}$. However, in the last decades commercial and academic MIP solver vendors, e.g., CBC, CPLEX, GUROBI, FICO XPRESS, SAS, and SCIP, continuously improved. Nowadays, large-scale real world application such as production planning (Pochet and Wolsey, 2006; Gamrath et al., 2019), scheduling (Lach and Lübbecke, 2010; Heinz and Beck, 2012; Heinz, 2018), power supply (Morales-España et al., 2015), transportation (Borndörfer et al., 2010), telecommunication networks (Lee and Lewis, 2006) and others can be solved in reasonable time. For an in-depth overview on the progress in solving MIPs we refer to the surveys of Bixby (2002), Lodi (2010), and Achterberg and Wunderling (2013).

A recurring concept used in solving MIPs is the linear programming (LP) relaxation. As mentioned above, we are talking about an LP if it hold $\mathcal{I} = \emptyset$. For every MIP the LP relaxation is derived by neglecting all integrality conditions. The LP relaxation of (2.1) reads as

$$c^\star_{LP} := \min \{c^\mathsf{T} x \,|\, Ax \geq b,\ \ell \leq x \leq u\}. \tag{2.2}$$

By neglecting the integrality conditions problem (2.2) is less restrictive than (2.1). Consequently, it hold $c^\star_{LP} \leq c^\star_{MIP}$, i.e., the optimal objective value of the LP relaxation yields a lower bound to the optimal objective value of the MIP. The dual LP of (2.2) reads as

$$\max \{b^\mathsf{T} y + \ell^\mathsf{T} r^\ell - u^\mathsf{T} r^u \,|\, A^\mathsf{T} y + r^\ell - r^u = c,\ y \in \mathbb{R}^m_{\geq 0},\ r^\ell, r^u \in \mathbb{R}^n_{\geq 0}\}. \tag{2.3}$$

In contrast to MIP, LPs can be solved in polynomial-time (Khachiyan, 1979; Karmarkar, 1984). However, the most often used technique for solving LPs is the simplex algorithm (Dantzig, 1951), especially the dual simplex algorithm (Lemke, 1954; Beale, 1954). In theory, for most pivot rules the simplex algorithm has an exponential worst-case run time (Klee and Minty, 1972). Gartner and Ziegler (1994) have shown that Dantzig's simplex algorithm needs on average quadratic many steps on Klee-Minty cubes when eligible pivots are made randomly instead of following the rule of steepest-descent. The main benefit of using the dual simplex algorithm instead of

the polynomial-time methods by Khachiyan and Karmarkar is the so-called *warm start* capability of the dual simplex. Both dual and primal simplex compute a solution and a corresponding *basis*. The basis is a subset of variables of size m such that the constraint matrix A restricted to the corresponding columns is regular. All remaining variables (so-called *non-basis*) are set to one of its finite bounds. The variables in the basis are set to the unique solution satisfying the set of constraints (Bertsimas and Tsitsiklis, 1997). From an optimal basis the dual simplex algorithm can warm start after variables bounds or constraint right-hand sides have changed, e.g., due to branching, or constraints were added. By exploiting the warm start capability the effort needed by the simplex algorithm is significantly reduced. This property becomes in handy within one of the most frequently used methods in solving MIPs: the branch-and-bound procedure.

2.2 The Branch-and-Bound Procedure

The branch-and-bound procedure dates back to Land and Doig (1960) and Dakin (1965). Nowadays, LP-based branch-and-bound is the most commonly used method in state-of-the-art MIP solvers, extended by various sophisticated features and improvements. In this section, we will describe the basic idea of branch-and-bound for solving MIPs.

Branch-and-bound is a divide-and-conquer method that splits the search space sequentially into smaller and smaller subproblems, which are intended to be easier to solve. Let us denote the original problem (2.1) by $\mathcal{P}_0$. During the branch-and-bound procedure a list of unprocessed problems Ω, which is initialized with $\mathcal{P}_0$, is maintained. The procedure terminates if the list of unprocessed problems Ω is empty. Next to the list of unprocessed problems an upper bound $\overline{c}$ on the optimal solution is maintained. In the beginning the upper bound is initialized to ∞.

As long as Ω is not empty a subproblem $\mathcal{P}'$ is selected, removed from Ω, and its LP relaxation solved. Let $\check{x}$ be an optimal relaxation solution and $c^\star_{LP}(\check{x})$ the optimal objective value of $\check{x}$. The following four cases needs to be considered:

1. The relaxation of $\mathcal{P}'$ is infeasible. The subproblem can be discarded. Note, no feasible relaxation solution $\check{x}$ exists in that case.

2. The optimal objective value exceeds the upper bound, i.e., $c^\star_{LP}(\check{x}) \geq \overline{c}$. The subproblem cannot contain an integer feasible solution with a smaller objective value than $\overline{c}$. The subproblem can be discarded.

3. $\check{x}$ is feasible for $\mathcal{P}'$, i.e., $\check{x}_j \in \mathbb{Z}$ for all $j \in \mathcal{I}$ and $c^\star_{LP}(\check{x}) < \overline{c}$. Store $\check{x}$ as new incumbent (best-known solution) and update $\overline{c} := c^\star_{LP}(\check{x})$. Discard $\mathcal{P}'$ because it cannot contain a better solution, i.e., it solved to optimality.

4. $\check{x}$ is infeasible for $\mathcal{P}'$, i.e., $\exists j \in \mathcal{I}$ such that $x_j \notin \mathbb{Z}$, and $c^\star_{LP}(\check{x}) < \overline{c}$. Divide $\mathcal{P}'$ into k smaller subproblems and add them to Ω.

The name branch-and-bound is derived from Steps 4 and 2 which are called *branching* and *bounding*, respectively. For solving MIPs the branching rules (see Section 2.5) used in Step 4 typically split problem $\mathcal{P}'$ into disjoint subproblems. However, this is not needed to ensure correctness. Further, let $\mathcal{S}(\mathcal{P}')$ be the set of integer feasible solutions of $\mathcal{P}'$. The disjunction $\mathcal{P}'_1, \ldots, \mathcal{P}'_k$ of $\mathcal{P}'$ constructed in Step 4 has to satisfy $\mathcal{S}(\mathcal{P}') = \bigcup_{p=1}^{k} \mathcal{S}(\mathcal{P}'_p)$. Note, the subproblems created during branching are required to be MIPs. Therefore, they can only be created by changing variable bounds or adding linear constraints.

In this thesis, we are especially interested in infeasibilties encountered in Steps 1 and 2. Step 1 described the "classical" type of LP-induced infeasibilty because the LP relaxation is infeasible itself. Thus, the infeasibility of subproblem $\mathcal{P}'$ is independent from the ordering in which the problems are evaluated. In contrast to that, Step 2 describes a type of infeasibilty which depends in the incumbent solution and, therefore, on the ordering in which the yet unprocessed subproblems are evaluated. In Chapter 4 we will discuss how to account for this variability.

2.3 The Farkas Lemma

In this section we will introduce and prove the central theorem which is the fundament of LP-based conflict analysis.

Theorem 1 (Farkas Lemma (Farkas, 1902))**.** *Let $A \in \mathbb{R}^{m \times n}$ and $b \in \mathbb{R}^m$. Then exactly one of the following conditions holds:*

(a) $\exists x \in \mathbb{R}^n$ *such that* $Ax = b$, $x \geq 0$

(b) $\exists y \in \mathbb{R}^m$ *such that* $y^\mathsf{T} A \leq 0$, $b^\mathsf{T} y > 0$

Before we can prove the Farkas lemma we need the following statements about convex sets.

Theorem 2 (Separating Hyperplane (e.g., Boyd and Vandenberghe, 2004))**.** *Let $\mathcal{P}, \mathcal{Q} \subset \mathbb{R}^n$ be convex, nonempty, and disjoint sets. Then there exists a hyperplane $\mathcal{H} := \{x \in \mathbb{R}^n \mid \alpha^\mathsf{T} x = \beta\}$ with $\alpha \neq 0$ and $\beta \in \mathbb{R}$ separating $\mathcal{P}$ and $\mathcal{Q}$.*

Hyperplane $\mathcal{H}$ is a separating hyperplane of $\mathcal{P}$ and $\mathcal{Q}$ if $\mathcal{P} \cup \mathcal{Q} \nsubseteq \mathcal{H}$, $\mathcal{P} \subseteq \{x \in \mathbb{R}^n \mid \alpha^\mathsf{T} x \leq \beta\}$, and $\mathcal{Q} \subseteq \{x \in \mathbb{R}^n \mid \alpha^\mathsf{T} x \geq \beta\}$ hold. To prove the Farkas lemma we need a special version of the separating hyperplane theorem that allows strict separation. Note that neither inequality in Theorem 2 can be made strict. This is illustrated by the following example and Figure 2.1.

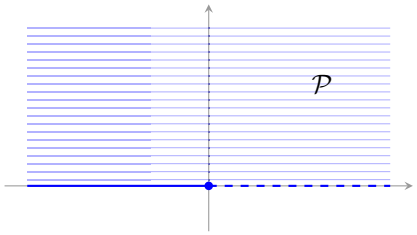


Figure 2.1: Example for which neither inequality in Theorem 2 can be made strict.

Example 3. *Let* $\mathcal{P} := \{(x_1, x_2) \in \mathbb{R}^2 \mid x_2 \geq 0,\, x_2 > 0 \,\forall x_1 > 0\}$ *and let* $\overline{\mathcal{P}} \subset \mathbb{R}^2$ *be its complement. Both sets are convex and do not intersect by construction. Theorem 2 holds for* $\alpha = (0, -1)^\mathsf{T}$ *and* $\beta = 0$*. However, there does not exist* α, β *such that* $\alpha^\mathsf{T} x \leq \beta$ *for all* $x \in \mathcal{P}$ *and* $\alpha^\mathsf{T} x > \beta$ *for all* $x \in \overline{\mathcal{P}}$*.*

Theorem 4 (Strict Separating Hyperplane (e.g., Boyd and Vandenberghe, 2004))**.** *Let* $\mathcal{P}, \mathcal{Q} \subset \mathbb{R}^n$ *be closed and convex sets, with at least one of them bounded, and* $\mathcal{P} \cap \mathcal{Q} = \emptyset$*. Then there exists* $\alpha \in R^n$ *with* $\alpha \neq 0$ *and* $\beta \in \mathbb{R}$ *such that* $\alpha^\mathsf{T} x < \beta$ *for all* $x \in \mathcal{P}$ *and* $\alpha^\mathsf{T} x > \beta$ *for all* $x \in \mathcal{Q}$*.*

From the strict separating hyperplane theorem we can immediately conclude the next statement which we finally need to prove Theorem 1.

Corrolary 5. *Let* $\mathcal{P} \subset \mathbb{R}^n$ *be a closed convex set and* $x \in \mathbb{R}^n$ *with* $x \notin \mathcal{P}$*. Then there exists a hyperplane strictly separating* $\mathcal{P}$ *and* x*.*

The connection of the separating hyperplane and the Farkas lemma can be illustrated by its geometric interpretation, see Figure 2.2. A set $\mathcal{K} \subseteq \mathbb{R}^n$ is called a *cone* if $x \in \mathcal{K} \implies \lambda x \in \mathcal{K}$ for all $\lambda > 0$. Moreover, given a set $\mathcal{S} \in \mathbb{R}^n$. By $\text{cone}(\mathcal{S}) := \{\sum_{j=1}^n \lambda_j x_j \mid \lambda_j \geq 0,\, x_j \in \mathcal{S}\}$ we denote the *conic hull* of $\mathcal{S}$, i.e., the set of all conic combinations of points in $\mathcal{S}$. The geometric interpretation of the Farkas lemma is as follow. Consider all columns $A_{\cdot 1}, A_{\cdot 2}, \ldots, A_{\cdot n}$ of A and the cone of their nonnegative combinations. If b is not in the cone of A's columns, i.e., statement (a) of Theorem 1 does not hold, then there exists a hyperplane separating b and $\text{cone}(A_{\cdot 1}, A_{\cdot 2}, \ldots, A_{\cdot n})$.

Proof of Theorem 1.

(i) We show that (a) and (b) cannot be satisfied at the same time.
Let $\bar{x}$ and $\bar{y}$ be the x and y from (a) and (b), respectively. Since $\bar{x} \geq 0$ it follows $y^\mathsf{T} A \leq 0 \implies y^\mathsf{T} A x \leq 0$. Moreover, it follows by (a) that $0 \geq y^\mathsf{T}(Ax) = y^\mathsf{T} b$, which contradicts $y^\mathsf{T} b > 0$.

(ii) We show that if (a) does not hold, then (b) does hold. Let $A_{\cdot 1}, A_{\cdot 2}, \ldots, A_{\cdot n}$ be the column vectors of A. Let $\mathcal{K} := \{u \in \mathbb{R}^m \mid u = \sum_{j=1}^n \lambda_j A_{\cdot j}, \lambda_j \geq 0 \,\forall j = 1, \ldots, n\}$

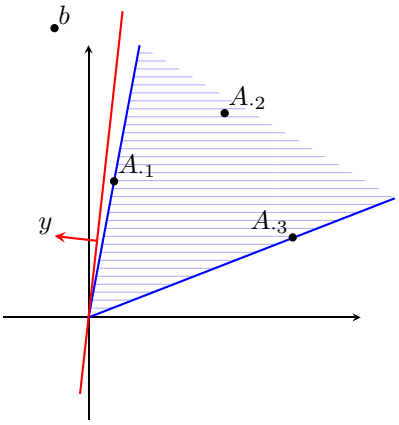


Figure 2.2: Geometric interpretation of the Farkas lemma.

be the cone spanned by the column vectors of A. Since $Ax = \sum_{j=1}^{n} x_j A_{\cdot j}$, there exists an $x \geq 0$ such that $Ax = b$ if and only if $b \in \mathcal{K}$. Since we assume that (a) does not hold, it follows $b \notin \mathcal{K}$. We can apply Corrolary 5 to b and $\mathcal{K}$ because $\mathcal{K}$ is not empty, closed, and convex. The separating hyperplane theorem implies that there exists an $\alpha \in \mathbb{R}^m$, with $\alpha \neq 0$, and $\beta \in \mathbb{R}$ such that $\alpha^\mathsf{T} b > \beta$ and $\alpha^\mathsf{T} v < \beta$ for all $v \in \mathcal{K}$. Note, $0 \in \mathcal{K}$ implies $\beta > 0$. Moreover, it holds $\lambda A_{\cdot j} \in \mathcal{K}$, for all $\lambda \geq 0$. Since it holds $\alpha^\mathsf{T} v < \beta$ for all $v \in \mathcal{K}$, it follows $\alpha^\mathsf{T}(\lambda A_{\cdot j}) < \beta$ and, therefore, $\alpha^\mathsf{T} A_{\cdot j} < \beta/\lambda$ for all $\lambda > 0$. Because of $\beta/\lambda \to 0$ for $\lambda \to \infty$, it follows $\alpha^\mathsf{T} A_{\cdot j} \leq 0$. Finally, by setting $y := \alpha$, we obtain $y^\mathsf{T} b > 0$ and $y^\mathsf{T} A_{\cdot j} \leq 0$ for all $j = 1, \ldots, n$. Therefore, it follows $y^\mathsf{T} A \leq 0$ because $A_{\cdot j}$ are the columns of A.

□

The System (a) of Theorem 1 is an LP in standard form. Since every LP can be transformed into an equivalent LP in standard the following version of the Farkas lemma can be formulated.

Corrolary 6 (Matousek and Gärtner (2007))**.** *Let $A \in \mathbb{R}^{m \times n}$ and $b \in \mathbb{R}^m$. Then exactly one of the following conditions holds:*

(a) $\exists x \in \mathbb{R}^n$ *such that* $Ax \geq b$, $x \in \mathbb{R}^n$

(b) $\exists y \in \mathbb{R}^m_{\geq 0}$ *such that* $y^\mathsf{T} A = 0$, $b^\mathsf{T} y > 0$

As an immediate consequence we can formulate the following version of the Farkas lemma which we will used in the remainder of this thesis.

Corrolary 7. *Let $A \in \mathbb{R}^{m \times n}$ and $b \in \mathbb{R}^m$. Then exactly one of the following conditions holds:*

(a) $\exists x \in \mathbb{R}^n$ *such that* $Ax \geq b$, $\ell \leq x \leq u$

(b) $\exists y \in \mathbb{R}^m_{\geq 0},\ r^\ell, r^u \in \mathbb{R}^n_{\geq 0}$ *such that* $y^\mathsf{T} A + r^\ell - r^u = 0,\ b^\mathsf{T} y + \ell^\mathsf{T} r^\ell - u^\mathsf{T} r^u > 0$

Proof. Construct a matrix $\overline{A} \in \mathbb{R}^{(m+2n)\times n}$ and a vector $\overline{b} \in \mathbb{R}^{m+2n}$ such that

$$\overline{A} := \begin{bmatrix} A \\ I_n \\ -I_n \end{bmatrix} \quad \text{and} \quad \overline{b} := \begin{bmatrix} b \\ \ell \\ -u \end{bmatrix}.$$

By construction, every solution $x \in \mathbb{R}^n$ satisfying $Ax \geq b,\ \ell \leq x \leq u$ is a solution of $\overline{A}x \geq \overline{b}$. By Corollary 6 we know that if $\overline{A}x \geq \overline{b}$ is infeasible, there exists $z \in \mathbb{R}^{m+2n}$ such that $z^\mathsf{T}\overline{A} = 0$ and $\overline{b}^\mathsf{T} z > 0$. Define vectors $y \in \mathbb{R}^m_{\geq 0},\ r^\ell, r^u \in \mathbb{R}^n_{\geq 0}$ by

$$\begin{aligned} y_i &:= z_i && \forall 1 \leq i \leq m \\ r^\ell_j &:= z_{m+j} && \forall 1 \leq j \leq n \\ r^u_j &:= z_{m+n+j} && \forall 1 \leq j \leq n. \end{aligned}$$

Thus, it follows $0 = z^\mathsf{T}\overline{A} = y^\mathsf{T} A + r^\ell - r^u$ and $0 < \overline{b}^\mathsf{T} z = b^\mathsf{T} y + \ell^\mathsf{T} r^\ell - u^\mathsf{T} r^u$ which concludes the proof. □

2.4 Conflict Analysis

Conflict analysis is widely established in solving SAT/CP and MIP. This section gives an overview of the origin of conflict analysis and how it is used in solving SAT and in modern MIP solvers. The concepts discussed in this section define the starting point for all remaining chapters in this thesis.

2.4.1 Conflict Analysis in SAT Solving

We will briefly review the concept of conflict analysis in SAT solving (e.g., Marques-Silva and Sakallah, 1999; Zhang et al., 2001). SAT solving aims to solve the so-called *satisfiability problem* (SAT), which is defined as follows.

Definition 8 (satisfiability problem)**.** *Let* $\mathfrak{C} = \mathcal{C}_1 \wedge \ldots \wedge \mathcal{C}_m$ *be a logical formula in conjunctive normal form on Boolean variables* $x_1, \ldots, x_n$*. For every* $i = 1, \ldots, m$ *clause* $\mathcal{C}_i := \omega^i_1 \vee \ldots \vee \omega^i_k$ *is a disjunction of literals, where every literal* $\omega \in \Omega := \{x_1, \ldots, x_n, \overline{x}_1, \ldots, \overline{x}_n\}$*, i.e., it is either a variable* x_j *or its negation* $\overline{x}_j$*. The task of the* satisfiability problem *is to either find an assignment* $x^\star \in \{0,1\}^n$ *such that* $\mathfrak{C}$ *is satisfied or to conclude that* $\mathfrak{C}$ *is unsatisfiable.* $\mathfrak{C}$ *is called satisfied by* $x^\star$ *if each clause* $\mathcal{C}_i$ *evaluates to* 1*.* $\mathfrak{C}$ *is called unsatisfiable if for every* $x \in \{0,1\}^n$ *at least one clause evaluates to* 0*.*

Solving the satisfiability problem is $\mathcal{NP}$-complete (Cook, 1971). Modern SAT solvers such as MINISAT (Eén and Sörensson, 2004) and CHAFF (Moskewicz et al., 2001) implement a branching scheme (DPLL) (Davis and Putnam, 1960; Davis et al., 1962), the propagation of Boolean constraints (Zabih and McAllester, 1988), restarts in a periodic fashion (Gomes et al., 1998), and the analysis of infeasible subproblems (Marques-Silva and Sakallah, 1999).

Similar to branching schemes used for solving MIPs, the DPLL-algorithm used for solving SAT fixes one variable to 0 or 1 at each node of the search tree. Further fixings can be deduced by applying Boolean constraint propagation. On a clause $\mathcal{C}_i = \omega_1^i \vee \ldots \vee \omega_k^i$ the domain propagation rule reads

$$\omega_j^i = 0 \implies \omega_l^i = 1 \quad \forall j \in \{1, \ldots, k\} \setminus \{l\}. \tag{2.4}$$

In other words, if removing false literals in an undecided clause reduces the clause to a single literal (*unit clause*), the literal can be fixed to 1. This propagation rule is applied iteratively until either no further deduction can be derived or a clause becomes empty. The latter case is called *conflict*, to which *conflict analysis* can be applied. The clause implying the conflict is called *conflict clause*. Afterwards, the infeasible subproblem gets discarded and the branching scheme continues with an unprocessed node.

The branching steps and the deductions derived from constraint propagation can be visualized as a directed acyclic graph $G = (V, A)$. The graph is called *conflict graph*. An example of a conflict graph is shown in Figure 2.3. The vertices $V = \{\omega_1, \ldots, \omega_k, \lambda\} \subset \Omega \cup \{\lambda\}$ of the conflict graph represent assignments of values to the literals, including an artificial vertex λ representing infeasibility. The set of arcs A represents all deductions derived from constraint propagation. For every clause $\mathcal{C}_i = \omega_1^i \vee \ldots \vee \omega_k^i$ that became a unit clause by propagation there exists set of arcs $A_i := \{(\overline{\omega}_1^i, \omega_k^i), \ldots, (\overline{\omega}_{k-1}^i, \omega_k^i)\} \subset A$, where ω_k^i is the remaining literal in the unit clause. Analogously, there exists a set of arcs $A_\lambda := \{(\overline{\omega}_1^\lambda, \lambda), \ldots, (\overline{\omega}_{k-1}^\lambda, \lambda)\} \subset A$ implied by conflict clause $\mathcal{C}_\lambda$.

The goal of conflict graph analysis is to find conflict clauses – potentially different to $\mathcal{C}_\lambda$ – from which conflicts can be derived. Every cut in the conflict graph separating the branching decisions $V_B \subset V$ from the infeasibility vertex λ gives rise to a distinct conflict clause. Let $V = V_R \cup V_C$, with $V_B \subset V_R$, $\lambda \in V_C$, and $V_R \cap V_C = \emptyset$, be a partition derived from a cut in G. The sets V_R and V_C are called *reason side* and *conflict side*, respectively. From the partition a *conflict set* $V_{RC} := \{\omega_j \in V_R \,|\, (\omega_j, \omega_i) \in A,\, \omega_i \in V_C\}$ arises. Further, from every conflict set a conflict clause

$$\mathcal{C}_{RC} := \bigvee_{\omega_j \in V_{RC}} \overline{\omega}_j \tag{2.5}$$

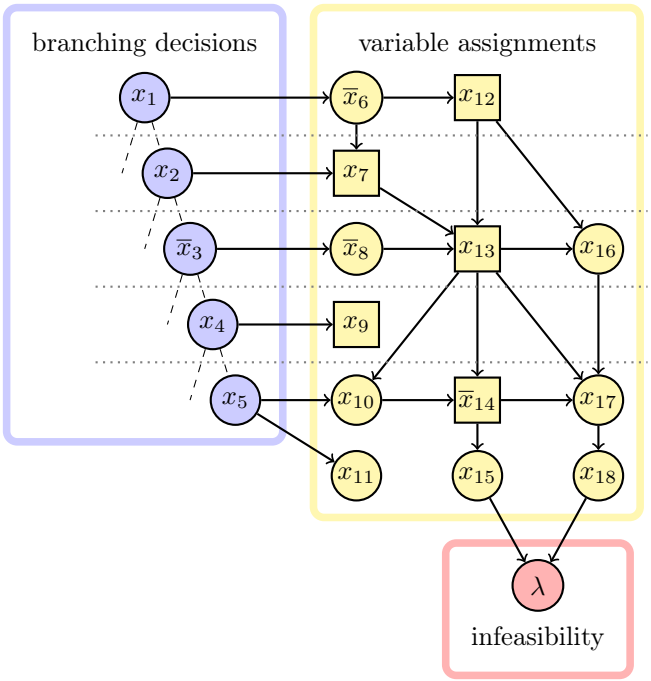


Figure 2.3: Example of a conflict graph describing all variable assignments from the branching decisions to the infeasibility λ due to propagation. FUIPs are marked with a rectangular shape. Depth levels are separate by horizontal dotted lines.

can be constructed, which is valid for all feasible solutions of the SAT instance.

A widely used concept for constructing good cuts in G are the so-called *unique implication points* (UIP). UIPs exist for every depth level, which are illustrated by vertical dotted lines in Figure 2.3.

Definition 9 (unique implication point)**.** *Let d be a depth level and $\omega_j^d \in V$ be a literal representing a fixing in depth level d. The literal ω_j^d is called* unique implication point (UIP) *if every path from the branching vertex of depth level d to the infeasibility λ goes through ω_j^d or a UIP $\omega_{j'}^{d'}$ of depth level $d' > d$.*

The UIP of depth level d that is met first when traversing from the infeasibility λ to the branching vertex of depth level d, i.e., when traversing in reverse order, is called *first unique implication point* (FUIP) of level d. The FUIP of each depth level is represented with a rectangular shape in Figure 2.3. Zhang et al. (2001) have demonstrated that using the so-called *All-FUIP* and *1-FUIP* schemes performs best when solving SAT instances. Let $\omega_j^d \in V$ be the FUIP of depth level d. A partition $V = V_R \cup V_C$ induced by ω_j^d can be constructed by

- assigning all literals fixed after ω_j^d to the conflict side V_C,

- assigning FUIP ω_j^d and all remaining literals to the reason side V_R.

The 1-FUIP scheme consists of the partition induced by the FUIP of the last depth level. The All-FUIP scheme consists of assigning all variables fixed by the FUIPs of all depth levels to V_C and both the FUIPs of all depth levels and the remaining variables to the reason side.

Further concepts of conflict analysis in SAT are *reconvergence cuts* and *non-chronological backtracking*. The first concept relies on another class of cuts introduced by Zhang et al. (2001) which do not require separating the branching vertices from the infeasibility λ. This class of cuts is required for applying non-chronological backtracking, which is used if conflict analysis yields a clause with a single literal fixed on the same depth level where the conflict was detected. If all necessary reconvergence cuts are generated the opposite fixing of the literal can be performed at an appropriate smaller depth level.

2.4.2 Infeasibility Analysis in MIP

Conflict analysis for MIP has its origin in solving satisfiability problems (SAT) and goes back to Marques-Silva and Sakallah (1999). Similar ideas are used in constraint programming (CP) (e.g., Ginsberg, 1993; Jiang et al., 1994; Stallman and Sussman, 1977). Integration of these techniques into MIP was independently suggested by Achterberg (2007b); Davey et al. (2002); Sandholm and Shields (2006). In this thesis, we mostly follow the concepts and the notation of Achterberg (2007a,b).

Nowadays, the analysis of infeasible subproblems is widely established in solving MIPs. Most state-of-the-art MIP solvers rely either on an adaption of the conflict graph analysis techniques known from SAT/CP or a pure LP-based approach. Both approaches are strongly connected, as we will argue below.

Assume, we are given an infeasible subproblem

$$\min\{c^\mathsf{T} x \,|\, Ax \geq b,\ \ell' \leq x \leq u',\ x_j \in \mathbb{Z}\, \forall j \in \mathcal{I}\} \tag{2.6}$$

of (2.1) defined by local bounds $\ell \leq \ell' \leq u' \leq u$. In LP-based branch-and-bound, the infeasibility of a subproblem is typically detected by contradicting implications, i.e., during domain propagation, or by an infeasible LP relaxation (see Steps 1 and 2 in Section 2.2).

2.4.2.1 Infeasibility due to Domain Propagation

If infeasibility is encountered by domain propagation, modern SAT and MIP solvers construct a directed acyclic graph as described in Section 2.4.1. The conflict graph represents the logic of how the set of branching decisions led to the detection of infeasibility.

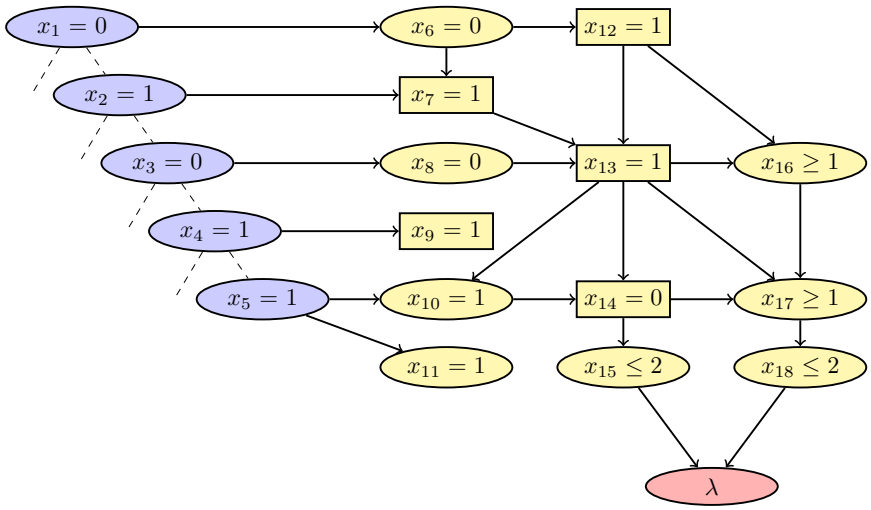


Figure 2.4: Example of a generalized conflict graph describing all deduced variable bound changes from the branching decisions to the infeasibility λ due to propagation, with $x_1, \ldots, x_{14}$ binary and $x_{15}, \ldots, x_{18}$ general integer.

Note, the term "conflict graph" is often used differently in the MIP community. In MIP, the conflict graph describes implication between two binary variables (Atamtürk et al., 2000). This graph is used for, e.g., deriving clique cuts (Johnson and Padberg, 1982; Savelsbergh, 1994). To preserve the relation to conflict analysis as performed in SAT we will use the term "conflict graph" with the SAT-like interpretation when talking about MIP, too.

Analogous to conflict analysis in SAT solving, the goal of conflict analysis in MIP is to find good cuts in the conflict graph G separating the branching decisions V_B from the artificial infeasibility vertex λ. In contrast to SAT, MIP might also contain general integer and continuous variables. To consider non-binary variables within conflict analysis Achterberg (2007b) introduced a *generalized conflict graph*, see Figure 2.4. The general idea of representing the deductions derived from domain propagation is preserved in the generalized conflict graph, however, the vertices of the generalized conflict graph are associated with bound changes $\underline{\beta}_j^\mu := \{x_j \geq \mu\}$ and $\overline{\beta}_j^\mu := \{x_j \leq \mu\}$ instead of literals $\omega_j \in \Omega$, i.e., binary variable assignments. For simplicity of notation let $\beta_j^\mu \in \{\underline{\beta}_j^\mu, \overline{\beta}_j^\mu\}$.

Based on a cut in G, a conflict constraint can be derived consisting of a set of variables with associated bounds, requiring that in each feasible solution at least one of the variables has to take a value outside these bounds. Note that in general, conflict constraints derived from this procedure have no linear representation if general integer or continuous variables are present. Moreover, similar to conflict analysis in SAT, several different conflict constraints might be derived from a single infeasibility by using different cuts in the graph.

The construction of a conflict set V_{RC} follows the description in Section 2.4.1 and is based on the reason side V_R and conflict side V_C which are inducing the selected cut, i.e., $V_{RC} := \{\beta_j^\mu \in V_R \,|\, (\beta_j^\mu, \beta_i^{\mu'}) \in A,\, \beta_i^{\mu'} \in V_C\}$. If the conflict set contains only bound changes on binary variables, the corresponding conflict clause (2.5) has a linear representation and can be written as a set covering constraint

$$\sum_{j\colon x_j \in V_{RC}} (1 - x_j) + \sum_{j\colon \overline{x}_j \in V_{RC}} x_j \geq 1. \tag{2.7}$$

In contrast to that, if the conflict set contains at least one non-binary variable j the conflict clause does not have a linear representation. The associated conflict clause reads

$$\bigvee_{j\colon \underline{\beta}_j^\mu \in V_{RC}} (x_j < \mu) \vee \bigvee_{j\colon \overline{\beta}_j^\mu \in V_{RC}} (x_j > \mu). \tag{2.8}$$

For all variables x_j with $j \in \mathcal{I}$ the individual clause can be tightened to $(x_j \leq \mu - 1)$ if $\underline{\beta}_j^\mu \in V_{RC}$ or $(x_j \geq \mu + 1)$ if $\overline{\beta}_j^\mu \in V_{RC}$. A nonlinear constraint of type (2.8) is called *bound disjunction constraint* (Achterberg, 2007b).

Analogous to solving SAT, the well-established strategies 1-FUIP and All-FUIP for finding good cuts in the (generalized) conflict graph can be applied. In an intense computational study Achterberg (2007a) demonstrated that a different strategy is beneficial for solving MIPs. This strategy outperformed both strategies. The proposed strategy considers the FUIPs of all branching levels and the corresponding conflict constraints. In his computational study, Achterberg (2007b) proposed choosing at most 10 of the most promising conflict constraints among all generated conflict constraints with respect to infeasibility λ.

2.4.2.2 Infeasibility due to an Infeasible LP Relaxation

During LP-based branch-and-bound, the LP relaxation of each subproblem is solved. If the LP relaxation turns out to be infeasible, the procedure described in Section 2.4.2.1 cannot be applied directly. The reason is that the LP does not deduce infeasibility from a single constraint, but from the inequality system (2.6) incorporating local bound changes as a whole. Naïvely, one would only have to consider all local bound changes as a reason for the infeasibility. However, this would not allow learning a conflict constraint that can be used for pruning the tree elsewhere. Although the naïve reason of infeasibility does not provide additional information for the remainder of the search, it can be used as a starting point for conflict graph analysis that might lead to more general conflict constraints. However, it is desirable to identify a small set of variables

and bound changes sufficient to render the LP infeasible. In the following, we will refer to such a set of variables as *initial set*. Note, the initial set of variables is not unique in general. An initial set of variables can be identified by using LP duality theory and a greedy heuristic as described by Achterberg (2007a). If only binary variables are present, a conflict constraint encodes that in every feasible solution at least one variable in the constraint has to take a different value compared to the current path along to the root node. Obviously, adding a variable would weaken the conflict constraint (Iwama, 1997). Thus, in the case of conflict graph analysis, which is a combinatorial approach, sparser conflict constraints are preferred. A heuristic approach for achieving short conflict constraints is to start from a minimal subset of the initial set of variables that is sufficient to render infeasibility (Achterberg, 2007a). Note, there might be multiple minimal subsets of the initial set of variables that render infeasibility.

Based on such a minimal subset of variables the same procedure as applied to analyze infeasibility due to domain propagation can be used to derive conflict constraints from an infeasible LP relaxation. Achterberg proposed to pursue the same strategy for analyzing LP-based infeasibility (see the end of this section) as for analyzing infeasibility due to domain propagation.

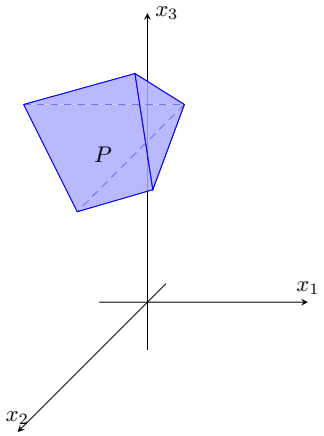
In the following parts of this thesis, we propose and consider a different strategy considering the LP-based certificate of infeasibility directly, i.e., the so-called *initial dual proof constraint*. Compared to conflict graph analysis, which is seeded from a single (minimal) subset of the initial set of variables, the initial dual proof constraint encodes all subsets of the initial set of variables that render infeasibility. Thus, it encodes more information. However, this does not mean that a single dual proof constraint dominates all conflict constraints that can be derived from it. As mentioned above, the initial set of variables is not unique in general. Thus, after applying conflict graph analysis the resulting conflict constraints might contain variables whose bounds have been changed along the root path but are not part of the initial set.

If solving the LP relaxation detects infeasibility, the proof of infeasibility is given by a ray in the dual space with respect to the zero-objective function[1]. Consider a node of the branch-and-bound tree and the corresponding subproblem of type (2.6) with local bounds $\ell \leq \ell' \leq u' \leq u$. Remember, the dual LP of the corresponding LP relaxation of (2.6) as defined in (2.3) is given by

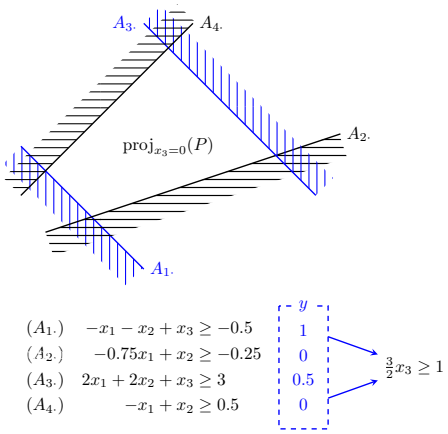
$$\max\{y^\mathsf{T} b + \sum_{j \in \mathcal{N}} (r_j^\ell \ell'_j - r_j^u u'_j) \,|\, y^\mathsf{T} A + r^\ell - r^u = c,\ y \in \mathbb{R}^m_{\geq 0},\ r^\ell, r^u \in \mathbb{R}^n_{\geq 0}\},$$

where $r^\ell, r^u \in \mathbb{R}^n_{\geq 0}$ represent the vector of dual variables on the finite bound constraints, i.e., for every variable j the reduced costs are given by $r_j := r_j^\ell - r_j^u$. Note, since every

[1] This does not require that the dual problem of (2.2) is feasible.



(a) Polytope P



(b) Projection of P. Dual multipliers y and the resulting dual proof constraint.

Figure 2.5: Illustration of an infeasibility proof. The polytope $P = \{x \in \mathbb{R}^3 \mid Ax \geq b,\ 0 \leq x_j \leq 1 \text{ for } j = 1,2,3\}$ representing the convex hull of the global problem $\min\{0^\mathsf{T}x \mid Ax \geq b,\ x \in \{0,1\}^3\}$. After branching in x_3, the subproblem with $x_3 = 0$ can be proven to be infeasible due to an infeasible LP relaxation. The resulting dual proof constraint is $x_3 \geq \frac{2}{3}$ which lead to the global bound deduction $x_3 \geq 1$.

unfixed variable j can only be tight in at most one bound constraint, it follows by complementary slackness that either r_j^ℓ, r_j^u, or none of them will be different to zero but not both at the same time in an optimal solution. For every variable x_j it holds that $r_j = c_j - y^\mathsf{T}A_{\cdot j}$, where $A_{\cdot j}$ denotes the j-th column of A. By LP theory, each ray $(y, r) \in \mathbb{R}^{m+n}$ in the dual space that satisfies

$$\begin{aligned} y^\mathsf{T}A + r &= 0 \\ y^\mathsf{T}b + \textstyle\sum_{j\in\mathcal{N}}(r_j^\ell \ell'_j - r_j^u u'_j) &> 0 \end{aligned} \tag{2.9}$$

proves infeasibility of (2.6), i.e., in combination with the local bounds ℓ' and u', which is an immediate consequence of the Lemma of Farkas (1902), see Theorem 1 and Corollary 7. Hence, if (2.6) is infeasible, there exists a solution (y, r) of (2.9). System (2.9) implies an infeasibility proof with respect to ℓ' and u'

$$\begin{aligned} & 0 < y^\mathsf{T}b + \sum_{j\in\mathcal{N}}(r_j^\ell \ell'_j - r_j^u u'_j) \\ \iff \quad & 0 < y^\mathsf{T}b - \sum_{j\in\mathcal{N}:\ y^\mathsf{T}A_{\cdot j}<0}(y^\mathsf{T}A_{\cdot j})\ell'_j - \sum_{j\in\mathcal{N}:\ y^\mathsf{T}A_{\cdot j}>0}(y^\mathsf{T}A_{\cdot j})u'_j \\ \iff \quad & (y^\mathsf{T}A)\{\ell', u'\} < y^\mathsf{T}b, \end{aligned}$$

where we use the shorter notation of

$$\begin{aligned}(y^\mathsf{T}A)\{\ell', u'\} &:= \sum_{j\in\mathcal{N}:\ y^\mathsf{T}A_{\cdot j}<0} (y^\mathsf{T}A_{\cdot j})\ell'_j + \sum_{j\in\mathcal{N}:\ y^\mathsf{T}A_{\cdot j}>0} (y^\mathsf{T}A_{\cdot j})u'_j \\ &= \max_{x\in[\ell',u']} y^\mathsf{T}Ax.\end{aligned} \tag{2.10}$$

By construction, the inequality

$$y^\mathsf{T}Ax \geq y^\mathsf{T}b \tag{2.11}$$

is a nonnegative aggregation of globally valid constraints, therefore, it has to be fulfilled by all feasible solutions. In the following, this type of constraint will be called *dual proof constraint*. The dual ray is effectively a list of multipliers on all constraints that are represented in the LP relaxation, such as model constraints (needed by the problem formulation) or additional valid global inequalities, e.g., cutting planes, conflict constraints, and dual proof constraints. Thus, aggregating the constraints according to the multipliers leads to a globally valid but redundant constraint. However, with respect to the local bounds ℓ' and u' it leads to a false statement, thereby proving that the set described by the constraints is empty inside the local bounds. The property of proving infeasibility with respect to at least one set of local bounds distinguishes dual proof constraints from arbitrary constraint aggregations. It is used as some kind of natural "filtering" among the infinitely many different possible constraint aggregations.

In general, infeasibility analysis can also be applied as explained in this thesis if locally valid inequalities are present. Here, we assume the corresponding dual multiplier to be 0. The resulting dual proof might not prove local infeasibility anymore. In this case, the analysis of the infeasibility is stopped immediately. A modifications of infeasibility analysis that also incorporate locally valid inequalities is described in Section 7.3.

The situation of local infeasibility can be exploited as follows: Either one starts conflict analysis as described in Section 2.4.2.1 from the initial set of local bounds, or one considers only the weights given by the dual ray on the model constraints (Pólik, 2015a,b). If the model constraints are aggregated with respect to the dual multipliers, omitting the local bounds, we derive a new globally valid constraint, which can be used for domain propagation. In the following, we refer to the latter as *dual proof analysis* and to the outcome of this approach as *dual proof constraint*. For the remainder of this thesis, we will refer to the classical conflict analysis as described in Achterberg (2007a) as *conflict graph analysis* in order to better disambiguate the two concepts. We will speak about the analysis of infeasible subproblems if we refer to both concepts together.

An example of an infeasible LP after branching on one variable and the resulting dual proof constraint can be found in Figure 2.5. In this case, a single bound change

is derived, but in general, the resulting constraint can be directly used for domain propagation during the remainder of the search.

In practice, a dual proof constraint of type (2.11) is expected to be dense, and therefore, it might be worthwhile to search for a sparser infeasibility proof. Therefore, we will discuss in the following how this constraint can be sparsified and strengthened via *dual proof analysis*. Both the original and strengthened dual proof constraint can be used as a starting point for *conflict graph analysis*, which is already described for infeasibility due to domain propagation in Section 2.4.2.1.

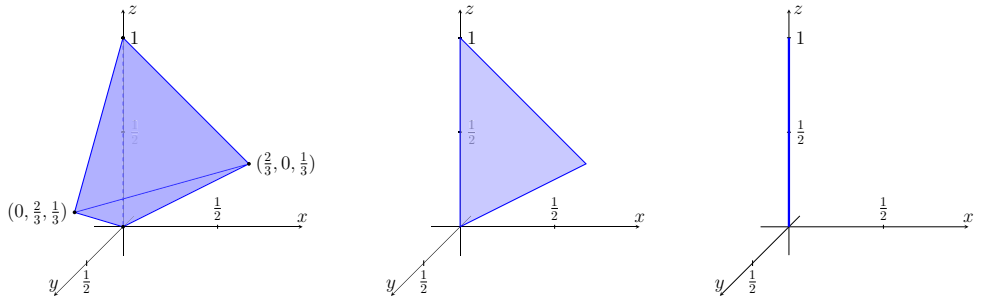
Dual Proof Analysis. Dual proof analysis denotes the construction and modification of a dual proof constraint (2.11). In general, all presolving techniques that apply to a single constraint (e.g., Achterberg, 2007b; Achterberg et al., 2020; Savelsbergh, 1994), can be used. In Section 3.3, we will especially elaborate on presolving reductions that preserve the local proof of infeasibility. The outcome of dual proof analysis is a single linear constraint that can be used in the remainder of the search to derive further bound deductions and prove the infeasibility of other parts of the tree. Further, it is a starting point for the conflict graph analysis. Dual proof constraints are directly derived from the LP relaxation. In contrast to conflict constraints derived from conflict graph analysis, dual proof constraints do not incorporate any knowledge about integrality or inferences of variables. Therefore, dual proof constraints are only considered for domain propagation. Thus, they do not enter the LP relaxation.

Conflict Graph Analysis. To use the concept of a conflict graph as described in Section 2.4.2.1, one needs an initial, preferably small, reason for infeasibility. Such encoding of infeasibility with respect to local bounds ℓ' and u' can be constructed from an infeasibility proof of type (2.11): It suffices to consider only local bounds of variables that have a nonzero coefficient in (2.11). The vertices of the conflict graph that correspond to those local variable bounds changes are then connected to the artificial sink representing the infeasibility; global bounds are omitted. Conflict graph analysis can be applied as described in Section 2.4.2.1.

As mentioned in a side note in Section 2.4.2.2, Achterberg (2007a) introduced a heuristic to strengthen conflict graph analysis. The heuristic relaxes some of the local bounds $[\ell', u']$ that appear in the dual proof constraint such that the relaxed local bounds $[\ell'', u'']$ with $\ell < \ell'' \leq \ell' \leq u' \leq u'' < u$ still fulfill

$$y^\mathsf{T} b + \sum_{j \in \mathcal{N}} (r_j^\ell \ell_j'' - r_j^u u_j'') > 0.$$

Note, the more bounds can be relaxed, the smaller the initial reason gets and the stronger the resulting conflict constraints (Iwama, 1997).



(a) LP relaxation.

(b) LP relaxation after conflict graph analysis.

(c) LP relaxation after dual proof analysis.

Figure 2.6: Illustration of Example 10.

Example 10. *A main difference between using a dual proof directly instead of applying conflict graph analysis is the consideration of variables that contribute with their global bound. Consider the following MIP*

$$\begin{aligned} \max\ & x + y + z \\ s.t.\quad & x + y + 2z \leq 2 \\ & x + y - 2z \leq 0 \\ & x + y + z \leq 1 \\ & x, y, z \in \{0, 1\}. \end{aligned}$$

An optimal solution of the LP relaxation is $(0, \frac{2}{3}, \frac{1}{3})$ *with objective value* 1. *After branching on* y*, the LP relaxation proves infeasibility of the subproblem with* $y = 1$. *A valid infeasibility proof, i.e., an unbounded ray in its dual, is* $(0, \frac{1}{2}, 1)$. *Following Section 2.4.2.2, the resulting dual proof constraint is* $1.5x + 1.5y \leq 1$. *Applying conflict graph analysis leads to a single global deduction:* $(y \leq 0)$*, see Figure 2.6b. In contrast to that, propagating the dual proof constraint directly leads to two global bound changes:* $(x \leq 0) \wedge (y \leq 0)$*, see Figure 2.6c.* □

2.5 Further Techniques used in a MIP Solver

So far, we discussed two concepts of a MIP solver, namely branch-and-bound and conflict analysis, that are especially relevant for the remainder of this thesis. In this section, we briefly introduce and discuss other important components of modern MIP solvers.

Nowadays, competitive MIP solvers still rely on the branch-and-bound procedure invented more than 50 years ago but use many additional techniques and tricks to accelerate the solving process. All ingredients together turn a MIP solver into very so-

phisticated tool. To illustrate the importance of the bag of tricks consider the following trivial optimization problem (Jeroslow, 1974)

$$\min\{-x_1 \mid 2\sum_{j=1}^{n} x_j = n\}, \tag{2.12}$$

with $n \in \mathbb{Z}$ odd and $x \in \{0,1\}^n$. Obviously, the left side of the expression is always even. Since n is odd by construction, the problem is infeasible, which is immediately detected by a modern MIP solver. However, Jeroslow (1974) has shown that a plain branch-and-bound procedure will end with a search tree of exponential size, independently from the branching rule.

Presolving. All existing competitive MIP solvers apply a transformation of the given instance into an equivalent instance that is intended to be easier to solve. This is what we call presolving. In practice, MIPs usually contain a lot of redundant data. Reasons might the use of modeling languages as ZIMPL[2], PYSCIPOPT[3], AMPL[4] or MOSEL[5] to mention only a few, or the fact that the MIP solver is at the end of a long chain of data transformations starting with an user interface, followed by passing several intermediate layers, e.g., premodeling steps, until the data reaches the MIP solver itself; as it happens, e.g., in SAP Integrated Business Planning for Supply Chain[6]. Thus, one main task of presolving is to remove the redundant data that would lead to a slow down of the solving process. Other tasks of presolving are the strengthening of the LP relaxation by exploiting, e.g., integrality information, and the extraction of information that might be useful in the remainder of the solving process, e.g., cliques. For detailed information on the most fundamental presolving techniques we refer to Savelsbergh (1994) or Achterberg et al. (2020) for details about the implementation in a leading state-of-the-art MIP solver.

Domain Propagation. In MIP terminology domain propagation is also called *node preprocessing*. Thus, domain propagation is a restricted version of presolving applied to single node of branch-and-bound tree. In contrast to preprocessing, the operations applied by domain propagation must not modify the constraints, e.g., no variables are allowed to be removed. The task of domain propagation is to tighten the domains of variables with respect to the local domains of other variables. To do so, domain propagation inspects the constraints and current domains of other variables.

In mixed integer programming, the only type of constraints is the linear constraint.

[2] https://zimpl.zib.de/
[3] https://github.com/SCIP-Interfaces/PySCIPOpt and see Maher et al. (2016)
[4] https://ampl.com/
[5] https://www.fico.com/de/latest-thinking/brochure/xpress-mosel-overview
[6] https://www.sap.com/products/integrated-business-planning.html

However, for constraints that satisfy certain properties special domain propagation techniques exist. Special types of linear constraints are, e.g., set covering constraints of form (2.7). One prominent example of domain propagation techniques for general linear constraints is the so-called *activity-based bound tightening scheme* (Brearley et al., 1975).

Branching Rules. The probably most challenging task raised over and over again during solving a MIP is to select a variable to branch on next. Making an optimal decision in this regard is $\mathcal{NP}$-hard (Liberatore, 2000). Thus, a MIP solver employs several branching rules with individual strategies for finding a proper variable and point within the local variable domain to branch on. Most common branching rules perform a binary branching, i.e., based on a branching point β they perform a simple disjunction of form $x_j \leq \beta - 1 \bigvee x_j \geq \beta$, with $x_j \in \mathbb{Z}$ and $\beta \in [\ell_j, u_j] \cap \mathbb{Z}$. The resulting subproblem $\mathcal{P}'_1$ and $\mathcal{P}'_2$ of $\mathcal{P}'$ are created by tightening the upper bound and lower bound of x_j to $\beta - 1$ and β, respectively. Afterwards, $\mathcal{P}'_1$ and $\mathcal{P}'_2$ enter the set of unexplored subproblems (see Section 2.2). Classical MIP branching rules are, e.g., most infeasible branching (Dakin, 1965; Wolsey, 1998; Lodi, 2010), pseudocost branching (Bénichou et al., 1971), and strong branching (Gauthier and Ribière, 1977; Linderoth and Savelsbergh, 1999; Achterberg et al., 2005). Based on the classical branching rules, hybrid methods such as strong branching with pseudocost initialization (Gauthier and Ribière, 1977) and hybrid branching (Achterberg and Berthold, 2009) are quite often used. Nowadays, also machine learning impacts the development of branching rules (Kılınç Karzan et al., 2009; Fischetti and Monaci, 2011; Le Bodic and Nemhauser, 2017).

Node Selection. An important decision during the branch-and-bound procedure is to determine which subproblem $\mathcal{P}' \in \Theta$ should be explored next. Depending the ordering the yet unexplored subproblems are evaluated at the time at which feasible and improving solutions are found. The time at which an almost optimal solution is found has a huge impact on the following search. If an almost optimal solution is found early in the solving process many parts of the search tree can be pruned that do not contain any better solution. Thus, the solving process might accelerate. Apart from that, considerations like memory consumption or node processing times are taken into account. Typical node selection rules used in a MIP solver are depth-first search (Dakin, 1965; Even, 2011), best-first search (Morrison et al., 2016), best-estimate search (Bénichou et al., 1971) as well as hybrid methods such as best-first search with plunging (Achterberg, 2007b) to mention only a few.

Primal Heuristics. Primal heuristics are incomplete methods without a gurantee of success. They aim to construct improving solutions, i.e., feasible solutions that improve

the upper bound. The bounding step (see Step 2 in Section 2.2) within the branch-and-bound process is based on the current upper bound. Thus, finding good solutions early improve the effectiveness of bounding. In Chapter 6 of this thesis, we discuss two primal heuristics that aim to construct feasible solutions based on information derived from infeasibility analysis performed prior during the search. These heuristics belong to the class of *diving heuristics*; they perform an incomplete tree search along a single path in the search tree. For an indepth overview of primal heuristics for mixed integer (non)linear programming we refer to Berthold (2014a).

Cutting Planes. The goal of a cutting plane is to cutoff the current fractional LP solution. To do so, the cutting plane separation procedure (Gomory, 1960; Wolsey, 1998) adds valid linear inequalities to the LP relaxation. As a consequence, the current LP relaxation is tightened. Thus, the dual bound improves. In 1960, Gomory showed that integer programs can be solved by sequentially adding cutting planes. If the data is rational, the integer program can be solved in finitely many steps. However, the more cuts are added, the more the algorithm struggles with numerical issues. A few decades later, Balas et al. (1996) demonstrated that the use of cutting planes within a branch-and-bound framework can lead to drastically performance improvement. Since then competitive MIP solvers employ several different cutting plane algorithms such as lifted flow cover cuts (Gu et al., 1999), 0-1/2-Chvátal-Gomory cuts (Caprara and Fischetti, 1996). For a survey on cuttings planes used in mixed integer programming we refer to Marchand et al. (2002) and the references therein.

Symmetry Handling. Symmetry is quite omnipresent in MIPs, especially if they appear in practice. Assume you would like to optimize the loading of a truck with rectangular boxes. In every feasible solution, boxes with identical properties such as outer dimensions and weight can be exchanged without changing the quality of the solution and its meaning. Formally speaking, this corresponds to a permutation on the set of variables. According to this permutation the corresponding solutions values can be permuted. To handle such properties of the model and to break symmetry a MIP solver might add constraints or change variable domains. For further details on symmetry handling and detection we refer to Margot (2010); Pfetsch and Rehn (2019); Hojny and Pfetsch (2019).

2.6 Computational MIP Terminologies

This thesis is highly focuses on computational impacts of the presented techniques. In this section, we will introduce the main key values and concepts we are using in the computational sections of the following chapters.

2.6.1 Performance Measures

The main metric we are using in this thesis to measure the computational impact is the impact on the performance of a MIP solver. Here, we are using indicators like solving time and the number of explored branch-and-bound nodes a MIP solver uses with and without the a respective technique. The indicators, e.g., solving times, of every individual instance in a test set are aggregated into single number by taking the average. In this thesis we are using the *shifted geometric mean* (Achterberg, 2007b). Let $n \in \mathbb{Z}_{\geq 0}$, $\mathcal{V} := \{v_1, \ldots, v_n\}$ with $v_i \geq 0$ for all $i = 1, \ldots, n$, and $s \geq 0$. The shifted geometric mean of $\mathcal{V}$ is given by

$$\text{sgm}(\mathcal{V}) := \sqrt[n]{\prod_{i=1}^{n}(v_i + s)} - s. \tag{2.13}$$

We use shifts $s = 1$ and $s = 100$ for solving time in seconds and explored branch-and-bound nodes, respectively. The idea of using the shifted geometric mean instead of the arithmetic mean is twofold. Firstly, by a using a shift, the impact of very easy instances in the mean is reduced. Secondly, the geometric mean reduces the impact of instances that are very close or at the time limit. Thus, when using the shifted geometric mean we aim to reduce the number of outliers in both directions.

Next to the pure solver performance in terms of running time, we are also interested in the impact of conflict analysis on the global dual bound during the branch-and-bound procedure. Apart from Chapter 6, the main task of conflict analysis techniques as presented in this thesis is to deduce new constraints and additional variable domain changes, which have an immediate impact on the strength of the (local) problem and LP relaxation. Sure, adding constraints and reducing (local) variable bounds might have an impact on the primal side as well. However, this is an appreciated side effect because heuristics might find better solutions earlier or detect infeasibility prior in the search due to less degree of freedom.

To measure the impact of primal heuristics, Berthold (2013) introduced the *primal integral* which measures the improvement of the primal bound's convergence towards an optimal solution over the whole solving time. Analogous to the primal integral, the *dual integral* can be defined. Here, we follow the notation of Berthold. To do so, we need to measure the *dual gap* (Berthold, 2014a) at a certain point in time first. Let $x^\star$ be an optimal or best-known solution of (2.1) and $\check{x}$ be an optimal solution of a

relaxation of (2.1). The dual gap γ^d of $\check{x}$ is defined by

$$\gamma^d(\check{x}) := \begin{cases} 0, & \text{if } c^\mathsf{T} x^\star = c^\mathsf{T} \check{x} = 0, \\ 1, & \text{if } c^\mathsf{T} x^\star \cdot c^\mathsf{T} \check{x} < 0, \\ \frac{|c^\mathsf{T} x^\star - c^\mathsf{T} \check{x}|}{\max\{|c^\mathsf{T} x^\star|, |c^\mathsf{T} \check{x}|\}}, & \text{otherwise.} \end{cases} \tag{2.14}$$

This definition is analogous to the *primal gap* γ^p as it is defined by Berthold (2013) and satisfies the same properties. Based on the dual gap, the *dual gap function* can be defined as follows. Let t_{max} be a limit on the solving time. The dual gap function $d: [0, t_{max}] \mapsto [0, 1]$ is defined by

$$d(t) := \begin{cases} 1, & \text{if no dual bound exists until } t, \\ \gamma^d(\check{x}(t)), & \text{otherwise,} \end{cases} \tag{2.15}$$

where $\check{x}(t)$ is the dual bound at time t. Analogous to the primal gap function, the dual gap function is a monotone decreasing step function. Whenever the global dual bound is tightened the dual gap function changes. Finally, the *dual integral* can be defined as follows. Let $T \in [0, t_{max}]$ and $t_i \in [0, T]$ with $i \in I$, where $I := \{1, \ldots, I-1\}$ are the points in time the dual bound changes. The dual integral is given by

$$D(T) := \int_{t=0}^{T} d(t)dt = \sum_{i=1}^{I} d(t_{i-1}) \cdot (t_i - t_{i-1}). \tag{2.16}$$

2.6.2 Performance Variability

The performance of a MIP solver is influenced by some unexpected variability. This variability can come from, e.g., switching the hardware the MIP solver is running, permuting columns and rows of the constraint matrix, adding redundant data etc. The literature describes this phenomenon as *performance variability*. In their tutorial, Lodi and Tramontani (2013) performed a very interesting experiment within the state-of-the-art MIP solver CPLEX. To every instance of their test set[7] a single trivial and redundant constraint was added. For every instance the variable ordering in the added constraint was permuted nine times resulting in nine virtually identical copies of every instances in the test set. After running CPLEX on every copy of the test set, Lodi and Tramontani observed a huge performance deviation. More precisely, in eight out of nine runs they observed a nontrivial performance speed up in term of a reduced solving time. One technical reason for this observation, i.e., the change of the ordering in which variables are loaded into the solver, was discussed by Fischetti and

[7] 38 instances from MIPLIB 2010 and COR@L on which CPLEX 12.2 explored at least 10,000 branch-and-bound nodes and spent at least 100 seconds CPU time.

Monaci (2012). Another reason for performance variability is the so-called *imperfect tie breaking* (Koch et al., 2011). Most of the techniques implemented in a MIP solver rely on an ordering of the variables. These orderings are defined by individual scoring functions of the respective technique, e.g., a scoring function to determine on which variable branching should be performed next as it is employed by all branching rules. As Koch et al. (2011) explained, scoring functions cannot be perfect in general, thus, a tie breaking mechanism is needed. Common approaches for tie breaking are, e.g., selecting the variable with the highest score that comes first in the ordering or making a random decision among all variables with the same score. It is not too hard to see, that adding constraints and variable bound reductions, as it happens during conflict analysis, might have an impact on the internal scoring functions. Consequently, it is very likely that a successful conflict analysis impacts the performance and might trigger variability although the derived conflict constraint does not lead to further deductions in the remainder of the search.

To account for the effect of performance variability as described by Lodi and Tramontani (2013) all experiments presented in this thesis were performed with at least three random seeds (Chapters 3 – 6) or different constraint permutations (Chapter 7). In our experiments, every combination of MIP (or MINLP) problem and random seed (or permutation) is treated as an individual observation. In this thesis, we will use the term "instance" when referring to a problem-seed (problem-permutation) combination.

2.6.3 Clustering of Instances

In the computational studies presented in this thesis we analyze the impact of the respective techniques on a general-purpose MIP solver. We follow a common approach and divide the used test sets into different subsets. These subsets are based on the hardness of the instances. To divide the test sets in an unbiased manner we follow the principle suggested by Achterberg and Wunderling (2013). Firstly, all instances from the test set are removed on which at least one considered solver configuration encountered a failure of some type. Secondly, all instances where the considered solver configurations finished with different optimal objective values due to numerical difficulties. We denote the remaining set of instances by "all", which distinguishes between instances for which every considered configuration hit the time limit ("timelimit") and instances that could be solved by at least one considered configuration ("1-opt"). Further, we consider the subset of 1-opt which we call "affected", i.e., instances where the number of explored tree nodes differs among solver configurations. Finally, the group of affected instances is divided into a hierarchy of increasingly harder classes "$\geq k$". Class "$\geq k$" contains all affected instances for which at least one setting needed at least k seconds.

Chapter 3

Computational Aspects of Infeasibility Analysis in Mixed Integer Programming

The analysis of infeasible subproblems plays an important role in solving mixed integer programs (MIPs) and is implemented in most major MIP solvers. There are two fundamentally different concepts to generate valid global constraints from infeasible subproblems: conflict graph analysis and dual proof analysis. While conflict graph analysis detects sets of contradicting variable bounds in an implication graph, dual proof analysis derives valid linear constraints from the proof of unboundedness of the dual LP.

In this chapter, we present three enhancements of dual proof analysis: presolving via variable cancellation, strengthening by applying mixed integer rounding functions, and a filtering mechanism. Further, we provide an intense computational study evaluating the impact of every presented component regarding dual proof analysis. Moreover, this chapter presents the first combined approach hat uses both conflict graph and dual proof analysis simultaneously within a single MIP solution process.

3.1 Introduction

In this chapter, we will focus on one specific component that is used in almost every state-of-the-art MIP solver: the analysis of infeasible subproblems. Without loss of generality, we consider MIPs of the form (2.1) as defined in Chapter 2 which reads as

$$\min\{c^\mathsf{T} x \,|\, Ax \geq b,\ \ell \leq x \leq u,\ x_j \in \mathbb{Z}\ \forall j \in \mathcal{I}\}$$

with objective coefficient vector $c \in \mathbb{R}^n$, constraint coefficient matrix $A \in \mathbb{R}^{m \times n}$, constraint right-hand side $b \in \mathbb{R}^m$, and variable bounds $\ell, u \in \overline{\mathbb{R}}^n$, where $\overline{\mathbb{R}} := \mathbb{R} \cup \{\pm\infty\}$. Furthermore, let $\mathcal{N} = \{1, \ldots, n\}$ be the index set of all variables, and let $\mathcal{I} \subseteq \mathcal{N}$ be the set of variables that are required to be integral in every feasible solution.

Remember, by omitting the integrality requirements, we obtain the *linear program (LP)* of form (2.2) which reads as

$$\min\{c^\mathsf{T} x \mid Ax \geq b,\ \ell \leq x \leq u,\ x \in \mathbb{R}^n\}.$$

The linear program (2.2) is called the *LP relaxation* of (2.1). The LP relaxation provides a lower bound on the optimal solution value of the MIP (2.1). This technique is an important ingredient of LP-based branch-and-bound (Dakin, 1965; Land and Doig, 1960), which is the most commonly used method to solve MIPs. For more general details on branch-and-bound we refer to Section 2.2 of this thesis and the references therein. For the remainder of this chapter it is important to remember that MIP solvers may encounter infeasible subproblems during the branch-and-bound procedure. Infeasibility can either be detected by contradicting implications, e.g., derived by domain propagation, or by an infeasible LP relaxation.

Modern MIP solvers try to "learn" from infeasible subproblems, e.g., by *conflict analysis* (Achterberg, 2007a). More precisely, each subproblem can be identified by its local variable bounds, i.e., by local bound changes that come from branching decisions and domain propagation (Savelsbergh, 1994) at the current node and its ancestors. If domain propagation detects infeasibility, one way of conflict learning is traversing the chain of decisions and deductions in a reverse fashion. This procedure allows to reconstruct the history of bound changes along the root path, and thereby identifying explanations for the infeasibility. If it can be shown that a small subset of the bound changes suffices to prove infeasibility, a so-called *conflict constraint* is generated. This constraint is exploited in the remainder of the search for domain propagation. Consequently, other parts of the search tree can be pruned, and additional variable bounds can be deducted.

The power of conflict analysis arises because branch-and-bound algorithms often repeat a similar search in slightly different contexts throughout the search tree. Conflict constraints address such situations and aim to avoid redundant work.

In a preliminary study (Witzig et al., 2017), we examined a vanilla approach of combining conflict graph analysis and dual proof analysis within SCIP. The present chapter builds upon this work. Our contribution is twofold: We describe various enhancements for dual proof analysis and present an extensive computational study of the described techniques. On affected instances, the methods presented in this chapter improve the performance of SCIP by 7 % in term of solving time and lead to a tree

size reduction of 6.4 % compared to the approach reported in Witzig et al. (2017).

The chapter is organized as follows. In Section 3.2, we present a pool-based approach for managing conflict conflict constraints. Section 3.3 describes three enhancements on dual proof analysis. We will discuss presolving techniques like cancellation and the application of mixed integer rounding functions to strengthen the resulting dual proof constraint. Moreover, we present an update mechanism that allows one to strengthen certain dual proof constraints during the tree search and a filtering method only to pick the most promising dual proof constraints. An intense computational study of the techniques presented in this chapter is given in Section 3.4. Additionally, this study contains – to the best of our knowledge – the first computational results within MIP solvers incorporating both conflict graph and dual proof analysis.

3.2 Managing Conflicts in a MIP Solver

Maintaining and propagating large numbers of conflict constraints might slow down a solver and create a big burden memory-wise. For instances with a high throughput of branch-and-bound nodes, a solver like SCIP might easily create hundreds of thousands of conflicts within an hour of running time. In order to avoid a slowdown or memory short-coming, an *aging mechanism* is used within SCIP. Aging is a concept inspired by SAT and CP solving which has been already described by Achterberg (2007b). Every time a conflict constraint is considered for domain propagation an age counter (individually for each constraint) is increased if no deduction was found. If a deduction is found, the age will be reset to 0. If the age reaches a predefined threshold the conflict constraint is permanently deleted.

In SAT and CP, this mechanism is a well-established method to drop conflict constraints that do not frequently propagate. In the case of MIP solving, there are two main differences concerning the branch-and-bound search compared to SAT and CP. First, domain propagation is most often not the most expensive part of node processing. Second, SAT and CP solvers often use a pure depth-first-search (DFS) node selection, while state-of-the-art MIP solvers use some hybrid between DFS and best-estimate-search or best-first-search (e.g., Bénichou et al., 1971; Linderoth and Savelsbergh, 1999; Achterberg, 2007b). Therefore, it frequently happens that the node processed next is picked from a different part of the tree.

In the following, we describe a pool-based approach to manage constraints derived conflict analysis. Here, a pool refers to a fixed-size array that allows direct access to a particular element and which is independent of the model itself. The *conflict pool* is used to manage all conflict constraints derived from conflict graph analysis,

independently whether they were derived from domain propagation or an infeasible LP relaxation. We maintain a second pool managing all constraints derived from dual proof analysis. We refer to the latter as *dual proof pool*. The number of constraints that can be stored within each pool at the same is limited. In our implementation (see Section 3.4.1) the maximal size of the conflict pool is limited by 10 000 conflict constraints at the same time. In contrast to that, the dual proof pool is limited by 175. We decided to maintain only a very restricted number of dual proof constraints because they are expected to be most useful in the neighborhood of the subproblem they were derived from (Achterberg, 2016). Moreover, as already discussed in Section 2.4.2, dual proof constraints are expected to be dense because of its analytic nature. Both pools allow a central management of constraints derived from conflict analysis independently from the model constraints, i.e., they can be propagated, checked or deleted separately, without the need to traverse through all constraints.

To drop conflict constraints that do not lead to deductions frequently we implemented an update-routine that checks the conflict pool regularly, e.g., any time we create the first new conflict at a node. Moreover, we still use the concept of aging to determine the conflict constraints that are rarely used in propagation. Within this update procedure the oldest conflict constraints are removed.

Beside the regular checks, the conflict pool is updated every time a new improving incumbent solution is found. We will elaborate on this updating scheme in Section 3.3.1.2 and 3.4.2.

3.3 Three Enhancements for Dual Proof Analysis

Dual proof constraints derived as described in Section 2.4.2.2 can be used directly in the remainder of the search. However, similar to conflict graph analysis, the dual proof constraint can be modified and strengthened. In this section, we describe presolving and updating steps for strengthening dual proof constraints. Moreover, we discuss how filtering steps can decide which dual proof constraint should be applied and which should be rejected.

3.3.1 Presolving and Strengthening

Presolving plays an important role in solving mixed integer programs (e.g., Achterberg, 2007b; Achterberg et al., 2020; Brearley et al., 1975; Guignard and Spielberg, 1981; Savelsbergh, 1994). In this section, we will discuss presolving techniques that can be applied to a single linear constraint preserving the property of proving local infeasibility.

Since we consider MIPs as defined in Section 2.1 of form $Ax \geq b$, thus, only constraints of type $a^\mathsf{T}x \geq b_0$ are discussed in the remainder of this section. However, in Section 3.3.2 we will stick to the notation used in the literature and consider constraints

of form $a^\mathsf{T}x \leq b_0$. Note, by scaling with -1, each representation can be transformed into the other. Many presolving and strengthening techniques use activity arguments, see Brearley et al. (1975). Formally, the *maximal activity* of a constraint $a^\mathsf{T}x \geq b_0$ with respect to the (local) bounds ℓ, u is given by

$$\Delta_{\max}(a, \ell, u) = \sum_{j \in \mathcal{N} \,:\, a_j > 0} a_j u_j + \sum_{j \in \mathcal{N} \,:\, a_j < 0} a_j \ell_j.$$

Analogously, the *minimal activity* is given by

$$\Delta_{\min}(a, \ell, u) = \sum_{j \in \mathcal{N} \,:\, a_j > 0} a_j \ell_j + \sum_{j \in \mathcal{N} \,:\, a_j < 0} a_j u_j.$$

Moreover, we will denote the *violation* of a constraint with respect to the (local) bounds ℓ and u by $\nu_{\text{viol}}(a, b_0, \ell, u) = b_0 - \Delta_{\max}(a, \ell, u)$. Hence, a constraint proves infeasibility with respect to ℓ and u if $\nu_{\text{viol}}(a, b_0, \ell, u) > 0$.

3.3.1.1 Cancellation

Cancellation is a presolving technique to reduce the number of nonzero coefficients in a constraint (Achterberg et al., 2020). One way of doing so is the summation of constraints. More precisely, adding an equality constraint to an inequality constraint will preserve the feasible region of an LP or a MIP. The crucial part of this presolving technique is to choose a pair of constraints and a scaling factor for the equality constraint such that the support of the modified inequality is reduced. In this section, we present two variants of cancellation that can be applied to dual proof constraints. Both variants have a linear run time in the size of the support of the modified constraint.

Cancellation with Variable Bounds. Dual proof constraints might contain variables that contribute to the maximal activity with their global bound. Since the local and global contributions to the maximal activity are equal, e.g., $a_j \ell' = a_j \ell$, those variables can be removed from the infeasibility proof without changing the violation. Let ℓ', u' be the current local bounds of an infeasible subproblem. Then, a new constraint $\phi_B(a)^\mathsf{T}x \geq \psi_B(b_0)$ that still proves local infeasibility can be constructed by

$$\phi_B(a)_j = \begin{cases} a_j, & \text{if } j \notin \mathcal{N}_B \\ 0, & \text{otherwise} \end{cases} \tag{3.1}$$

$$\psi_B(b_0) = b_0 - \sum_{j \in \mathcal{N}_B} a_j \{\ell_j, u_j\}, \tag{3.2}$$

where $\mathcal{N}_B := \{j \in \mathcal{N} \mid a_j < 0 \text{ and } \ell'_j = \ell_j \text{ or } a_j > 0 \text{ and } u'_j = u_j\}$.

Proposition 11. *Let $a^\mathsf{T}x \geq b_0$ be a globally valid constraint and $\phi_B(a)^\mathsf{T}x \geq \psi_B(b_0)$ be constructed as described in (3.1)– (3.2) with respect to the local bounds ℓ' and u'. Then, the following holds:*

(i) $\nu_{viol}(a, b_0, \ell, u) = \nu_{viol}(\phi_B(a), \psi_B(b_0), \ell, u)$, *and*

(ii) $\tilde{\mathcal{X}} := \{(\ell', u') \in \mathbb{R}^n \times \mathbb{R}^n \,|\, \ell \leq \ell' \leq u' \leq u,\ \Delta_{\max}(\phi_B(a), \ell', u') < \psi_B(b_0)\} \subseteq \mathcal{X} := \{(\ell', u') \in \mathbb{R}^n \times \mathbb{R}^n \,|\, \ell \leq \ell' \leq u' \leq u,\ \Delta_{\max}(a, \ell', u') < b_0\}$.

Proof. (i) This follows immediately by construction.

(ii) We show that for every subproblem defined by $(\ell', u') \in \tilde{\mathcal{X}}$ it follows that $a^\mathsf{T}\{\ell', u'\} < b_0$. In other words, every tuple of bound vectors that is proven to be infeasible after applying (3.1) and (3.2) is proven to be infeasible by the original infeasibility proof, too. With the following observation

$$\sum_{\substack{j \in \mathcal{N}_B \\ \phi_B(a)_j = 0}} a_j\{\ell', u'\} < \sum_{\substack{j \in \mathcal{N}_B \\ \phi_B(a)_j = 0}} a_j\{\ell, u\},$$

where we use the short notation as introduced in (2.10), it follows immediately that

$$\begin{aligned} &\Delta_{\max}(\phi_B(a), \ell', u') + \sum_{\substack{j \in \mathcal{N}_B \\ \phi_B(a)_j = 0}} a_j\{\ell', u'\} < \psi_B(b_0) + \sum_{\substack{j \in \mathcal{N}_B \\ \phi_B(a)_j = 0}} a_j\{\ell_j, u_j\} \\ \iff \quad &\Delta_{\max}(a, \ell', u') < b_0, \end{aligned}$$

where ℓ', u', ℓ, u are chosen to maximize every expression.

□

Proposition 11 shows that using variable bounds to cancel nonzero coefficients in a dual proof constraint leads to a weaker infeasibility proof in general, see Example 12.

Example 12. *Let $x + y + z \geq 2$ be a valid dual proof constraint with respect to $\ell' = (0, 0, 0)$ and $u' = (0, 0, 1)$ and $x, y, z \in \{0, 1\}$. By construction, the modified constraint will be $x + y \geq 1$. Obviously, $((0, 0, 0),\ (1, 0, 0)) \in \mathcal{X}$ but satisfies the modified constraint $x + y \geq 1$, i.e., $((0, 0, 0),\ (1, 0, 0)) \notin \tilde{\mathcal{X}}$, where $\mathcal{X}$ and $\tilde{\mathcal{X}}$ are defined as in Proposition 11.*

□

Note that in LP-based branch-and-bound, as it is implemented in most modern MIP solvers, branching is performed only on integer variables. Therefore, we suggest applying the cancellation procedure as described in this section only to continuous variables. In our implementation we pursue a slightly more conservative strategy where only continuous variables are removed that contribute with a global bound to the

maximal activity with respect to the current local bounds, i.e., depending on the sign of the coefficient in the dual proof it holds $\ell' = \ell$ and $u' = u$, respectively. We apply this cancellation as long as $\text{supp}(a) > 0.15 \cdot |\mathcal{N}|$, where $\text{supp}(a) := \{j \in \mathcal{N} \mid a_j \neq 0\}$ denotes the support of $a^\mathsf{T} x \geq b$. This threshold is identical to the default threshold used to decide whether a conflict constraint, i.e., an infeasibility certificate derived from conflict graph analysis, should be accepted.

For the special case of all $j \in \text{supp}(a) \cap \mathcal{I}$ are binary and all continuous variables contribute with a global bound, i.e., $j \in \text{supp}(a) \cap (\mathcal{N} \setminus \mathcal{I}) : j \in \mathcal{N}_B$, we apply a more sophisticated strategy. Consider a maximal set of binary variables $\mathcal{I}^{\max} \subset (\text{supp}(a) \cap \mathcal{I})$ which is not sufficient to prove infeasibility with respect to the local bounds ℓ' and u', i.e.,

$$\Delta_{\max}(a_{\mathcal{I}^{\max}}, \ell', u') + \Delta_{\max}(a_{\mathcal{N} \setminus \mathcal{I}^{\max}}, \ell, u) \geq b$$

but for any binary variable x_j with $j \notin \mathcal{I}^{\max}$ it holds

$$\Delta_{\max}(a_{\mathcal{I}^{\max} \cup j}, \ell', u') + \Delta_{\max}(a_{\mathcal{N} \setminus (\mathcal{I}^{\max} \cup j)}, \ell, u) < b \quad \forall j \in (\text{supp}(a) \cap \mathcal{I}) \setminus \mathcal{I}^{\max}.$$

If such a set exists, all continuous variables can be canceled with their global bound without weakening the dual proof if they are never sufficient to prove infeasibility, i.e.,

$$\Delta_{\max}(a_{\mathcal{I}^{\max}}, \ell', u') + \Delta_{\max}(a_{\mathcal{I} \setminus \mathcal{I}^{\max}}, \ell, u) + \Delta_{\min}(a_{\mathcal{N} \setminus \mathcal{I}}, \ell, u) \geq b.$$

In that case the assignment of one additional binary variable x_j with $j \notin \mathcal{I}^{\max}$ to its current local bound is always needed to prove infeasibility, independently from the assignment of the continuous variables.

Cancellation with Variable Bound Constraints. Next to variable bounds that are explicitly given by the problem formulations, modern MIP solvers detect and use so-called *variable bound constraints*, see, e.g., Padberg et al. (1985); Achterberg et al. (2020).

Definition 13 (Variable Bound Constraint)**.** *Let $b^l, b^u \in \overline{\mathbb{R}}, c \in \mathbb{R}$ with $c \neq 0$. A* variable bound constraint *has the form*

$$b^l \leq x_j + c y_k \leq b^u,$$

where x_j is a continuous or integer variable and y_k a binary or integer variable.

If $b^l = -\infty$ and b^u finite, the constraint gives an upper bound on x_j, while a lower bound on x_j is given if b^l is finite and $b^u = \infty$. A typical example of variable upper bound constraints are so-called big-M constraints $x_j \leq My$, where M is a (usually)

huge constant, and y_k is binary. Other typical use-cases are precedence constraints on start time variables in scheduling.

Let $\mathcal{N}_V \subseteq \text{supp}(a)$ be the index of a variable for which a compatible variable bound constraint exists. A variable bound constraint on variable x_j with $a_j > 0$ is compatible if it defines an upper bound. Analogously, a variable lower bound constraint on x_j is compatible if $a_j < 0$. Moreover, let $\mathcal{V}$ be an arbitrary set of compatible variable bound constraints with respect to a_j containing, for every j, at least one variable bound constraint

$$b_j^l \leq x_j + c_{jk} y_k \leq b_j^u$$

such that y_k is binary or general integer and x_j is general integer or continuous. Since y_k defines a bound on x_j, we identify variable bound constraint in $\mathcal{V}$ by the tuple (j, k).

Given the sets $\mathcal{N}_V$ and $\mathcal{V}$, one can construct an alternative proof $\phi_V(a)^\mathsf{T} x \geq \psi_V(b_0)$, where

$$\phi_V(a)_j = \begin{cases} 0, & \text{if } j \notin \mathcal{N}_V \\ a_j - \sum\limits_{(k,j)\in\mathcal{V}} a_k c_{kj}, & \text{if } j \in \mathcal{N}_V \end{cases} \tag{3.3}$$

$$\psi_V(b_0) = b_0 - \sum_{\substack{j\in\mathcal{N}_V \\ (j,k)\in\mathcal{V}}} a_j \{b_j^l, b_j^u\}. \tag{3.4}$$

Proposition 14. *Let $a^\mathsf{T} x \geq b_0$ be a globally valid dual proof constraint and $\phi_V(a)^\mathsf{T} x \geq \psi_V(b_0)$ be a modified constraint following (3.3)– (3.4) with respect to the local bounds ℓ' and u'. For every $j \in \mathcal{N}_V$ with $(j,k) \in \mathcal{V}$ and $b_j^l = \ell'_j + c_{jk}\{\ell'_k, u'_k\}$ or $u'_j + c_{jk}\{\ell'_k, u'_k\} = b_j^u$ it holds*

$$\nu_{viol}(a, b_0, \ell', u') = \nu_{viol}(\phi_V(a), \psi_V(b_0), \ell', u').$$

The proof of the proposition follows by construction because only variable bound constraints that are satisfied with equality with respect to the local bounds are used for substitution.

The substitution of variables with variable bound constraints does not necessarily lead to smaller support in general. However, it can improve the capability of propagating the modified infeasibility proof, e.g., by replacing continuous variables by discrete variables. The following Examples 15 and 16 show how cancellation with variable bound constraints improve the propagation. On the other hand, Example 17 shows that not every variable bound constraint is suitable, such that the modified constraint does not prove local infeasibility anymore.

Example 15. *Let* $x_1 + x_2 - \frac{1}{2}y \geq 1$, $x_1, x_2 \in \{0,1\}$ *with* $\ell_j = u'_j = 0$ *and* $u_j = 1$ *for* $j = 1, 2$, $y \in \mathbb{Z}$ *with* $0 \leq y \leq 4$. *Moreover, let* $y - 2x_1 \geq 0$ *be a variable lower bound constraint of* y. *Applying* (3.3) *and* (3.4) *leads to*

$$\left.\begin{array}{rrrrrrr} & x_1 & + & x_2 & - & 0.5y & \geq & 1 \\ - & x_1 & & & + & 0.5y & \geq & 0 \end{array}\right\} \implies x_2 \geq 1.$$

□

Example 16. *Let* $x_1 + x_2 - z \geq 1$, $x_1, x_2 \in \{0,1\}$ *with* $\ell_j = u'_j = 0$ *and* $u_j = 1$ *for* $j = 1, 2$, $z \in \mathbb{R}$ *with* $0 \leq z \leq M$ *and* $M > 2$. *Moreover, let* $z - Mw \geq 0$ *be a variable lower bound constraint of* z *with* $w \in \{0,1\}$. *Applying* (3.3) *and* (3.4) *leads to*

$$\left.\begin{array}{rrrrrrrr} x_1 & + & x_2 & - & z & & \geq & 1 \\ & & & + & z & - & Mw & \geq & 0 \end{array}\right\} \implies w = 0.$$

□

Example 17. *Let* $x_1 + x_2 - \frac{1}{2}y \geq 1$, $x_1, x_2 \in \{0,1\}$ *with* $\ell_j = u'_j = 0$ *and* $u_j = 1$ *for* $j = 1, 2$, $y \in \mathbb{Z}$ *with* $0 \leq y \leq 4$. *Constraint* $x_1 + x_2 - \frac{1}{2}y \geq 1$ *proves infeasibility with respect to to the local bound constraints* $x_1 \leq 0$ *and* $x_2 \leq 0$. *Moreover, let* $y - x_1 \geq 0$ *be a variable lower bound constraint of* y. *Applying* (3.3) *and* (3.4) *leads to*

$$\left.\begin{array}{rrrrrrr} & x_1 & + & x_2 & - & 0.5y & \geq & 1 \\ - & x_1 & & & + & y & \geq & 0 \end{array}\right\} \implies x_2 + 0.5y \geq 1.$$

The modified constraint $x_2 + 0.5y \geq 1$ *does not prove local infeasibility anymore.* □

In our implementation, we make use of both described cancellation strategies. Firstly, we try to replace continuous and general integer variables with a variable bound constraint that is tight with respect to the local bounds such that no additional nonzero coefficient is introduced and the proof of local infeasibility is preserved. Moreover, we only substitute continuous variables by general integer and binary variables and general integer variables by binary variables. To break ties, we consider the left- and right-hand side of the variable bound constraints (sides closer to zero are preferred) and the variable locks (Achterberg, 2007b) of the substitution variable x_k (more locks are preferred).

Afterward, we cancel continuous variables that contribute to the dual proof's activity with their global bound following the procedure and case distinction described above.

3.3.1.2 Updating Procedure

During the tree search, subproblems are pruned due to infeasibility or because of the corresponding LP is proven to exceed the solution value of the currently best-known solution. This threshold is called the *cutoff bound*. In general, an LP that is proven to exceed the cutoff bound can be transformed into an infeasible LP by adding a constraint

$$c^\mathsf{T} x \leq c^\mathsf{T} x^\star, \tag{3.5}$$

where $x^\star$ denotes the currently best-known solution. In the following, we will denote this solution as *incumbent solution*.

A valid proof that the LP relaxation exceeds the cutoff bound is given by every dual feasible solution (y, r^ℓ, r^u) fulfilling

$$y^\mathsf{T} b + \sum_{j \in \mathcal{N}} (r_j^\ell \ell'_j - r_j^u u'_j) > c^\mathsf{T} x^\star \tag{3.6}$$

$$\iff \quad y^\mathsf{T} b + (c - y^\mathsf{T} A)^\mathsf{T} \{\ell', u'\} > c^\mathsf{T} x^\star, \tag{3.7}$$

where r_j denotes the reduced costs of x_j for all $j \in \mathcal{N}$. A globally valid dual proof constraint can be derived from (3.7):

$$(y^\mathsf{T} A - c)^\mathsf{T} x \geq y^\mathsf{T} b - c^\mathsf{T} x^\star. \tag{3.8}$$

This dual proof constraint has to be fulfilled by all improving solutions. Constraint (3.8) is globally valid since it is a convex combination of all rows $A_{i\cdot}$ and the cutoff constraint (3.5) scaled by -1.

Proposition 18. *Let $x^\star$ be the incumbent solution and $(y^\mathsf{T} A - c)x \geq y^\mathsf{T} b - c^\mathsf{T} x^\star$ an infeasibility proof for a bound-exceeding LP with respect to local bounds ℓ' and u'. For every feasible solution $\bar{x}^\star$ with $c^\mathsf{T} \bar{x}^\star < c^\mathsf{T} x^\star$ the dual proof constraint can be strengthened to $(y^\mathsf{T} A - c)x \geq y^\mathsf{T} b - c^\mathsf{T} \bar{x}^\star$ by tightening the right-hand side. Afterwards, the strengthened constraint*

(i) still proves infeasibility with respect to ℓ' and u' and

(ii) is globally valid.

Proof. (i) $y^\mathsf{T} b + \sum_{j \in \mathcal{N}} (r_j^\ell \ell'_j - r_j^u u'_j) > c^\mathsf{T} x^\star > c^\mathsf{T} \bar{x}^\star$

(ii) By construction $(y^\mathsf{T} A - c)x \geq y^\mathsf{T} b - c^\mathsf{T} \bar{x}^\star$ is a convex combination of all rows $A_{i\cdot}$ and the strengthened constraint (3.5) scaled by -1. Hence, the dual proof constraint is globally valid.

□

In our implementation we use this updating scheme to strengthen dual infeasibility proofs derived from bound-exceeding LPs each time a new incumbent solution is found. Note, since dual proof constraints are only used for domain propagation the strengthening does not directly impact the LP relaxation.

3.3.2 Mixed-Integer Rounding

Applying *mixed integer rounding* (MIR) cuts (Nemhauser and Wolsey, 1988, 1990) was proven to be very successful (e.g., Bixby et al., 2004; Bonami et al., 2008b) when generating strong cutting planes for mixed integer programming. It has been shown (Nemhauser and Wolsey, 1988) that MIR cuts imply Gomory's mixed integer cuts (Gomory, 1960). The family of mixed integer rounding cuts has a wide range and covers structured and unstructured MIPs. In this section, we will focus on *complemented MIR* (Marchand and Wolsey, 2001) inequalities, and we will discuss how this well-established type of mixed integer rounding function can be used to strengthen dual proofs.

3.3.2.1 c-MIR Inequalities

The MIR procedure strengthens a single linear inequality by rounding the coefficients of integer variables.

Theorem 19 (see, e.g., Cornuéjols (2008))**.** *Consider a mixed integer set defined by a single inequality*

$$\mathcal{S} := \{(x, z) \in \mathbb{Z}^n_{\geq 0} \times \mathbb{R}^p_{\geq 0} \mid a^\mathsf{T} x + g^\mathsf{T} z \leq b\}.$$

Let $f_0 = b - \lfloor b \rfloor$ *and* $f_j = a_j - \lfloor a_j \rfloor$*. Then the inequality*

$$\sum_{j=1}^{n} \left(\lfloor a_j \rfloor + \frac{(f_j - f_0)^+}{1 - f_0} \right) x_j + \frac{1}{1 - f_0} \sum_{j=1\,:\; g_j<0}^{p} g_j z_j \leq \lfloor b \rfloor \tag{3.9}$$

is a valid inequality for $conv(S)$*.*

For the proof of this theorem, we refer to Cornuéjols (2008). Inequality (3.9) is called *MIR inequality*. Note, Theorem 19 defines the MIR inequality for nonnegative variables only. However, every variable with at least one finite bound can be shifted into the nonnegative space by complementing with one of its (finite) bounds. Complementing variables can also be used to strengthen the MIR inequality. A variant of the MIR inequality combined with a special scaling parameter was proposed by Marchand and Wolsey (2001).

Theorem 20 (Marchand and Wolsey (2001)). *Consider a mixed integer set defined by a single inequality*

$$\mathcal{S} := \{(x, z) \in \mathbb{Z}^n_{\geq 0} \times \mathbb{R}_{\geq 0} \mid a^\mathsf{T} x + z \leq b,\ x_j \leq u_j\, \forall j \in \mathcal{I}\}.$$

Let (T, C) be a partition of $\mathcal{I}$ and $\delta > 0$. A complemented-MIR *(c-MIR) for S associated with (T, C) and $\delta > 0$ is obtained by complementing variables in C and dividing by δ before generating the MIR inequality.*

$$\sum_{j \in T} G\left(\frac{a_j}{\delta}\right) x_j + \sum_{j \in C} G\left(\frac{-a_j}{\delta}\right)(u_j - x_j) \leq \lfloor \beta_0 \rfloor + \frac{z}{\delta(1 - f_0)},$$

where $\beta_0 = (b - \sum_{j \in C} a_j u_j)/\delta$, $f_0 = \beta_0 - \lfloor \beta_0 \rfloor$, and $G(d) = \left(\lfloor d \rfloor + \frac{(f_d - f_0)^+}{1 - f_0}\right)$.

In the context of cutting planes, the MIR inequality is usually built from a nonnegative linear combination of valid inequalities. A heuristic how to derive a proper nonnegative linear combination that separates a given point (x, z) was proposed in Marchand and Wolsey (2001), where (x, z) is valid for the LP relaxation but violates the integrality conditions. Using the dual ray (y, r) yields a nonnegative linear combination that is valid for the global problem, see 2.4.2. Thus, the MIR procedure can be applied to the resulting proof constraint.

3.3.2.2 Applying c-MIR to Dual Proofs

In the following, we will define the partition (T, C) of $\mathcal{I}$, such that we always choose the closest bound (Marchand and Wolsey, 2001). Formally, if $\ell \leq x \leq u$ is the given reference point it follows $C := \{j \in \mathcal{I} \mid x_j > (u_j - \ell_j)/2\}$ and $T := \mathcal{I} \setminus C$.

In contrast to the classical separation procedure, where an LP-valid point should be separated from the convex hull, no such point is given when analyzing a subproblem with an infeasible LP relaxation. Due to this fact, there exists a certain degree of freedom when choosing a reference point that is used for complementing the MIR inequality. The (arbitrary) reference point is used to compute the efficacy of the infeasibility proof before and after applying the c-MIR procedure. We aim to strengthen the initial proof of infeasibility such that it propagates well in the remainder of the search. Since we aim at using globally valid proofs, the global bounds need to be used when complementing the MIR inequality.

The question remains which reference point to use when complementing the MIR inequality. The LP solution of the root node or the incumbent solution is not related

to the current subproblem. In contrast to that, $\hat{x}$ with

$$\hat{x}_j = \begin{cases} u_j & \text{if } a_j < 0, \\ \ell_j & \text{if } a_j \geq 0 \end{cases}$$

is a natural choice because it is related to the variable bounds contributing to the constraint activity. However, always using the bounds contributing to the minimal activity according to the respective signs for complementing might in general lead to weak local proofs. We say an infeasibility proof is stronger (weaker) with respect to a given reference point than another infeasibility proof, if its violation with respect to the given reference point is larger (smaller). In case of separating an LP-feasible point, Marchand and Wolsey (2001) proposed using the closest global bound for every variable with respect to the LP-feasible reference point. In case of an infeasible LP relaxation no LP-feasible reference point exists, however, we can construct a locally valid reference point $\hat{x}'$ that minimizes the violation of the dual proof with respect to local bounds ℓ' and u'

$$\hat{x}'_j = \begin{cases} u'_j & \text{if } a_j < 0, \\ \ell'_j & \text{if } a_j \geq 0. \end{cases}$$

Based on the (local) reference point $\hat{x}'$ that minimizes the violation of the proof, we propose to use the (global) reference point $\bar{x}$ with

$$\bar{x}_j = \begin{cases} u_j & \text{if } \hat{x}'_j \geq \frac{u_j+\ell_j}{2}, \\ \ell_j & \text{if } \hat{x}'_j < \frac{u_j+\ell_j}{2} \end{cases}$$

to define the partition (T, C). By construction it holds $\bar{x}_j = \hat{x}'_j$ for every binary variable x_j. In contrast to that, for every general integer variable the reference point does not only depend on the sign of the respective coefficients but considers how much the conflicting bound has been tightened.

Figure 3.1 gives two examples of reference points $\hat{x}'$ and $\bar{x}$ depending on the infeasible subproblem and the global bounds. The figure shows the global bounding box $[0, 9] \times [0, 7]$ for $x \in \mathbb{Z}^2$, an infeasible subproblem (blue box), and a conflict constraint $a^\mathsf{T} x \leq b$ proving infeasibility of the respective subproblem. Note, for simplicity the convex hull of the feasible region is not shown in the illustration. The minimal activity of $a^\mathsf{T} x \leq b$ is achieved at $\ell' \leq \hat{x}' \leq u'$.

In our implementation, we either keep the dual infeasibility proof or the derived c-MIR inequality. To estimate which constraint might be most beneficial in the remainder

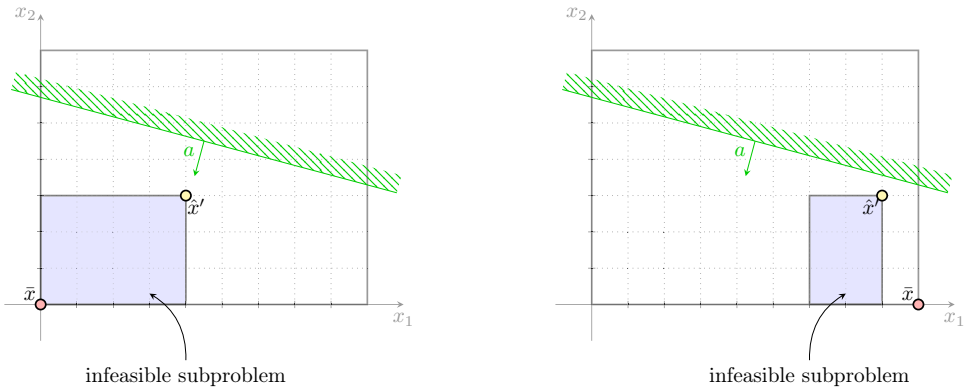


Figure 3.1: Illustrations of c-MIR reference point $\bar{x}$ compared to $\hat{x}'$, where $\hat{x}'$ minimizes the activity of $a^\mathsf{T}x \leq b$.

of the search, we consider the efficacy with respect to the described reference point $\bar{x}$, see Section 3.4.3 for further details.

3.3.3 Filtering

Conflict graph analysis and dual proof analysis share the initial reason of infeasibility $y^\mathsf{T}b + \sum_{j\in\mathcal{N}}(r_j^\ell \ell_j - r_j^u u_j) > 0$ as a common starting point (see Section 2.4.2). Both techniques follow different paths such that the resulting constraints are of very different nature. Conflict constraints derived from analyzing the conflict graph rely on combinatorial arguments. Consequently, these constraints are not challenging with respect to their numerical properties and expected to be sparse. Here, the shorter the conflict constraint, the stronger it is (Iwama, 1997). This observation becomes more apparent when looking at a conflict constraint from the SAT perspective, i.e., interpreting it as a set of clauses that cannot be all satisfied at the same time. Thus, adding a clause weakens the proof.

In contrast, constraints derived from dual proof analysis purely rely on the numerical conditions of the constraint set of the MIP and the properties of the dual proof obtained by solving the infeasible LP relaxation. Therefore, these proofs can be expected to be numerically more challenging and denser than those derived from analyzing the conflict graph. In the case of dual proofs, "sparser is better" does not hold anymore. Therefore, it is essential to pick the most promising infeasibility proofs derived from dual proof analysis. As opposed to conflict constraints derived by conflict graph analysis, dual proof constraints rely on the initial proof's coefficients because these coefficients are needed to define the constraint. We filter out dual proof constraints that might lead to numerically unstable propagation steps. This filtering is done by restricting the maximal absolute range of all coefficients. For a given constraint $a^\mathsf{T}x \geq b$ we consider

the minimal and maximal absolute coefficient which will be denoted by

$$a_{\min} := \min\{|a_j| \mid j \in \operatorname{supp}(a)\} \quad \text{and} \quad a_{\max} := \max\{|a_j| \mid j \in \operatorname{supp}(a)\}.$$

In our implementation we discard all proof constraints for which $a_{\max}/a_{\min}$ exceeds a threshold of 1e+8.

Dual infeasibility proofs derived by aggregating constraints $A_{i\cdot}$ weighted by a dual ray (y, r) are often dense, but it is a priori not clear whether sparse, i.e., short, dual proofs are to be preferred. The reason why longer proof constraints are assessed to be inferior against shorter proof constraints is twofold and hold for general constraints as well. It is expected that fewer bound changes on the support of a short constraint are necessary to derive new deductions. Therefore, constraints with small support are expected to propagate "earlier" than constraints with large support. Moreover, there are also technical reasons to prefer constraints with small support. Firstly, dense constraints consume more memory. Secondly, certain types of constraints are much more computationally costly to propagate than others. For example, consider a general linear constraint involving arbitrary variables and coefficients–which is most likely the case for a dual proof. Propagating a general linear constraint $a^\mathsf{T} x \geq b$, e.g., by activity-based bound tightening (Brearley et al., 1975), might be computationally costly with $\mathcal{O}(|\operatorname{supp}\{a\}|)$. In contrast to that, set covering constraints, which only contain binary variables, are very efficient to propagate in $\mathcal{O}(1)$ when using the 2-literal watching scheme (Moskewicz et al., 2001).

To not systematically abolish dense dual proof constraints, we propose a dynamic threshold on the size of its support to decide whether the proof should be accepted and maintained in the remainder of the search or immediately rejected. To this end, we consider the average density of all model constraints $A_{i\cdot}$, which will be denoted by

$$\operatorname{supp}_\emptyset(A) := \frac{\sum_{A_{i\cdot} \in A} |\operatorname{supp}(A_{i\cdot})|}{|A|}.$$

Further, let $\mathcal{C}$ be the set of all dual proofs currently maintained and $a^\mathsf{T} x \geq b$ a new dual proof. We accept the constraint if,

$$\operatorname{supp}_\emptyset(\mathcal{C} \cup \{a^\mathsf{T} x \geq b\}) \leq \max\{\alpha \operatorname{supp}_\emptyset(A),\ \beta|\mathcal{N}|\},$$

with $\alpha, \beta > 0$. By this, we do not restrict the density of a single constraint but rather the average density over the set of maintained dual proofs. Since dense dual proof constraints are expected to cover a larger variety of reasons of infeasibility but are computationally costly during domain propagation, we try to balance both properties.

With this strategy, we aim to adjust the threshold dynamically, depending on the actual density of all accepted dual proof constraints. Thus, if sufficiently many sparse dual proof constraints are maintained at the current point in time, we are willing to spend more effort on dense dual proof constraints. This strategy holds as long as the average expected effort does not exceed the dynamic threshold. Note that dual proof constraints with support of size one are immediately transformed into a bound change and, therefore, not included in the average density.

3.4 Computational Study

In this section, we present an extensive computational study on general MIP problems investigating the computational impact of the different ways of analyzing infeasibility in MIP presented in this chapter. To evaluate the individual impact of all the different techniques presented in this chapter, we will analyze each of them in detail.

In Section 3.4.1, we compare the impact of conflict graph analysis and dual proof analysis. Moreover, we present computational results where both techniques were simultaneously used within the state-of-the-art MIP solvers SCIP and FICO XPRESS. To the best of our knowledge, these are the first implementations of a combined approach within a single solver. In Section 3.4.2–3.4.4 we present individual computational results for all enhancement techniques presented in Section 3.3.

All experiments of Section 3.4.2 were performed with the academic MIP solver SCIP 5.1.0 using SOPLEX 3.1.1 as LP solver (Gleixner et al., 2017). The experiments in Section 3.4.1 were conducted with SCIP and FICO XPRESS 8.6.3[1]. To evaluate the generated data, the *interactive performance evaluation tool*[2] (IPET) was used. The SCIP experiments were run on a cluster of identical machines equipped with Intel Xeon E5-2690 CPUs with 2.6 GHz and 128 GB of RAM. The FICO XPRESS experiments were run on a cluster of identical machines equipped with Intel Xeon E5-2640 CPUs with 2.4 GHz and 64 GB of RAM. A time limit of 7200 seconds was set in either case.

As test set we used the newly released benchmark set of MIPLIB 2017[3].

To account for the effect of performance variability (Lodi and Tramontani, 2013) all SCIP experiments were performed with three different global random seeds; FICO XPRESS experiments were run on three different permutations of the problem. Determinism is preserved because SCIP and FICO XPRESS use pseudo-random number generators only. Every pair of MIP problem and seed/permutation is treated as an individual observation, effectively resulting in a test set of 720 instances. We will use

[1] https://www.fico.com/de/products/fico-xpress-optimization
[2] https://github.com/GregorCH/ipet
[3] http://miplib.zib.de

the term "instance" when referring to a problem-seed combination or a specific permutation of a problem.

In the following, we present aggregated results for every experiment containing the number of solved instances ($\mathbf{S}$) and the absolute and relative solving times in seconds ($\mathbf{T}$ and $\mathbf{T_Q}$) and the number of explored branch-and-bound nodes ($\mathbf{N}$ and $\mathbf{N_Q}$). The number of nodes is restricted to instances that were solved to optimality by all considered settings. Absolute numbers are always given for the baseline setting, whereas relative numbers are shown for all other settings. To aggregate the individual observations, a shifted geometric mean as defined in (2.13) is used, where a shift of 1 and 100 is used for solving time and nodes, respectively.

Relative solving times of setting s are defined by the quotient t_s/t_b, where t_s is the absolute solving time of setting s and t_b is the absolute solving time of setting b that is used as a baseline. An analogous definition holds for explored branch-and-bound nodes. Thus, numbers less than one imply that setting s is superior and numbers greater than one imply that it is inferior to the baseline setting b. Note, that a relative solving time t_s/t_b corresponds to a speedup factor of t_b/t_s.

Besides the results for the benchmark set of MIPLIB 2017[4], that are denoted by *all*, the tables state the impact on instances that are *affected*. An instance is called affected if it can be solved by at least one setting within the time limit and the number of tree nodes differs between settings. Further, the subset of affected instances is grouped into a hierarchy of increasingly harder classes "$\geq k$". Class "$\geq k$" contains all instances for which at least one setting needs at least k seconds and can be solved by at least one setting within the time limit. As explained by Achterberg and Wunderling (2013), this excludes instances that are "easy" for all settings in an unbiased manner. Detailed tables with instance-wise computational results regarding SCIP can be found in the online supplement[5] on GitHub.

3.4.1 General Overview

To analyze the overall computational impact of infeasibility analysis of infeasible LPs or bound exceeding LPs within SCIP, we consider four different configurations: disabled infeasibility analysis (`nolpinf`), conflict graph analysis (`confgraph`) or dual proof analysis (`dualproof`) solely, and using a combination of both techniques (`combined`). Note that all four settings only differ in how infeasible and bound exceeding LP relaxations are analyzed. Infeasibility due to propagation remains unchanged, see Table 3.1 for the different configurations of infeasibility analysis considered in this chapter. In the

[4] Excluding instances where at least one settings finished with numerical violations.
[5] https://github.com/jakobwitzig/computational-aspects-conflict-analysis-mip

Table 3.1: LP-based infeasibility analysis parameters of the different settings. Note, infeasibility due to propagation remains enabled in all settings.

Parameter	Description	Type	Value			
			`nolpinf`	`confgraph`	`dualproof`	`combined`
`useboundlp`	Analyze bound exceeding LPs.	char	`o`	`c`	`d`	`b`
`useinflp`	Analyze infeasible LPs.	char	`o`	`c`	`d`	`b`

Table 3.2: Aggregated computational results on MIPLIB 2017 benchmark. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

		`nolpinf`			`dualproof`			`confgraph`			`combined`		
		S	**T**	**N**	**S**	$\mathbf{T_Q}$	$\mathbf{N_Q}$	**S**	$\mathbf{T_Q}$	$\mathbf{N_Q}$	**S**	$\mathbf{T_Q}$	$\mathbf{N_Q}$
all	711	324	1482	2426	317	0.998	**0.938**	339	**0.916**	**0.855**	342	**0.897**	**0.823**
affected	283	254	532	6082	247	0.993	**0.923**	269	**0.799**	**0.820**	272	**0.759**	**0.782**
≥ 10	274	245	620	6824	238	0.991	**0.920**	260	**0.795**	**0.818**	263	**0.753**	**0.779**
≥ 100	228	199	1113	11847	192	0.977	**0.904**	214	**0.760**	**0.784**	217	**0.699**	**0.731**
≥ 1000	151	122	2387	34072	115	1.009	**0.933**	137	**0.697**	**0.731**	140	**0.628**	**0.686**

following, `nolpinf` is used as a baseline.

Both settings using dual proof analysis (`dualproof` and `combined`) were using all techniques described in Section 3.3. Aggregated results on all four settings are shown in Table 3.2.

For every LP relaxation considered for infeasibility analysis, at most 10 conflict constraints and 2 dual proof constraints are stored. As suggested by Achterberg (2007a), we store the 10 most promising conflict constraints generated by All-FUIP. When dual proof analysis is enabled, we store the modified and strengthened dual proof and the constraint after applying c-MIR to these proof constraints, if the procedure succeeds (see Section 3.4.3).

To maintain all conflict constraints and dual proofs, we use a pool-based approach as introduced in Section 3.2. Here, the maximal number of conflict constraints maintained at the same time when using `nolpinf`, `confgraph`, and `combined` was limited to 10,000. When using `dualproof` and `combined`, at most 100 dual proofs of infeasible and 75 dual proofs of bound exceeding LPs are maintained simultaneously. These pool sizes turned out to have the best trade-off between additional information and time spent in evaluating these constraints. A similar observation regarding the performance of dual proof analysis within GUROBI was made by Achterberg et al. (2020). If one of the pools reaches its limit, the constraint that did not lead to new bound deductions for the longest time is removed before adding the new conflict or dual proof constraint. This procedure corresponds to an aging scheme as it is used in SAT (Moskewicz et al., 2001).

Our computational results indicate that 80 % of the instances that can be solved by

at least one of the four settings are affected by analyzing infeasible and bound exceeding LP relaxations.

All three variants of LP infeasibility analysis are superior to SCIP without any of these techniques. Over all subsets of instances shown in Table 3.2 we observe a clear ordering. `combined` is superior to `confgraph`, and `confgraph` is superior to `nolpinf` with respect to both solving time and tree size. At the same time, `dualproof` is clearly inferior to both `confgraph` and `combined` but superior to `nolpinf` regarding tree size. Surprisingly, `dualproof` has hardly any impact regarding the solving time compared to `nolpinf`. However, the reduction of the tree size on affected instances by using dual proof analysis solely is 6.2 %. Here, our observations differ from those reported by Achterberg et al. (2020), where dual proof analysis leads to a reduction of solving time by 6 % on affected instances. The disparity in the observations may be caused by different test sets and a different implementation in Gurobi, which is tuned to rely solely on dual proof analysis.

The version that combines both conflict graph analysis and dual proof analysis (`combined`) solves 18 additional instances compared to `nolpinf` and 3 more instances compared to `confgraph`. In our experiments, the impact on the tree size by applying conflict analysis is consistently larger than the impact on the overall solving time. This observation is expected because every additional constraint derived from either of the presented techniques that is considered in the remainder of the search increases the time spent at every node of the search tree, i.e., during domain propagation.

On affected instances, we observed a success rate of 83 % for `combined`, i.e., the portion of analyzed infeasible and bound exceeding LP relaxations from which at least one conflict constraint or dual proof could be derived. `dualproof` and `confgraph` yield a success rate of 67 % and 34 %, respectively. The small success rate of `confgraph` is due to a very strict limit on the size of the support to accept a conflict constraint. Due to the combinatorial nature of conflict constraints, it is known that shorter is always better. Moreover, on the set of affected instances, bound exceeding LP relaxations were analyzed 3.3 to 4.4 times as often as infeasible LP relaxations.

On instances that are known to be infeasible, `confgraph` and `combined` perform best, reducing the solving time by roughly 65 %. In contrast to that, `dualproof` performs like `nolpinf`. Hence, we conclude that on infeasible instances, conflict graph analysis is superior to dual proof analysis. Note that, Miplib 2017 contains only 8 infeasible instances. Thus, our observation is based on a small test set of 24 instances. On the other hand, on the set of nontrivial feasibility instances[6] consisting of 57 instances, `confgraph` performs worse compared to the set of affected instances. Here, `confgraph` improves the solving time by 10.9 % (affected: 20.1 %) only. In contrast to that, `combined` improves the solving time by 24.5 % (affected: 24.1 %) and `dualproof`

[6]The set of instances with a nontrivial objective function for which the gap between the final dual bound at the root node and the best-known solution is below 0.1 %.

Table 3.3: Aggregated computational results on MIPLIB 2017 benchmark for FICO XPRESS. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

		nolpinf			confgraph			combined		
		S	**T**	**N**	**S**	**T_Q**	**N_Q**	**S**	**T_Q**	**N_Q**
all	693	515	77.5	7024	530	**0.926**	**0.889**	529	**0.909**	**0.874**
affected	350	330	225	58703	344	**0.847**	**0.835**	343	**0.833**	**0.813**
$\geq$ 10	306	286	394	58703	300	**0.832**	**0.835**	299	**0.815**	**0.813**
$\geq$ 100	224	204	948	60916	218	**0.780**	**0.833**	217	**0.767**	**0.812**
$\geq$ 1000	118	98	2794	86530	112	**0.706**	**0.821**	111	**0.699**	**0.799**

leads to slight slowdown of 2.3 %. Consequently, we conclude that the combination of both conflict graph analysis and dual proof analysis is particularly beneficial on feasibility instances.

Computational Impact of Infeasibility Analysis in FICO XPRESS. Table 3.3 shows the overall computational impact of using or a combination of conflict graph and dual proof analysis (`combined`), neither of the two (`nolpinf`) or only conflict graph analysis (`confgraph`) within the state-of-the-art commercial MIP solver FICO XPRESS. Using only dual proof analysis is not easily possible within the current FICO XPRESS implementation.

Independent of the actual experiments, there are some principal differences between the SCIP results and those of FICO XPRESS. We observed a significantly larger number of out of memory failures. The increase in the number of failures has three primary reasons. Firstly, the machines on which FICO XPRESS was run only have half the RAM compared to those of SCIP. Secondly, FICO XPRESS was run with 20 threads, which leads to 64 MIP tasks being created and, therefore, 64 copies of the problem being taken, see Berthold et al. (2017). Thirdly, the node throughput on hard problems was much larger. This can be partially seen in the "$\geq k$" rows, but naturally instances that time out or run out of memory are affected even more. This leads to a much larger search tree being created: for some instances, FICO XPRESS solved more than 100 million nodes. Instances for which at least one variant of FICO XPRESS hit the memory limit were removed, which is the reason for the smaller number of instances in the overall test set.

FICO XPRESS solved significantly more instances to proven optimality or infeasibility than SCIP. Since more instances are solved, the number of affected instances increases. At the same time, FICO XPRESS solved a larger share of instances at the root node; which decreases the number of affected instances. Consequently, the set of affected instances differs a lot between the two solvers, although the number (330 versus 283) is only slightly different.

Nevertheless, our observations show quite similar tendencies. As for SCIP, conflict

graph analysis gives a clear performance boost to the solver, and a combined approach of conflict graph and dual proof analysis gives the best performance. Altogether, we observe a speed-up of 9 %, when applying infeasibility analysis techniques in FICO Xpress. On affected instances, the speed-up is roughly 17 %, and goes up to 30 % on the hardest models. These numbers are smaller than the corresponding numbers for SCIP (10 % on all, 24 % on affected, 37 % on the hardest). Next to the different sets of affected instances, there is also a technical explanation for this deviation: The balancing between local cutting and infeasibility analysis differs between the two solvers. FICO Xpress separates significantly more cuts that are only locally valid, which constrains the applicability and the impact of infeasibility analysis. Consequently, only 65% of the solved instances are affected (compared to 80 % for SCIP).

As for SCIP, by using infeasibility analysis techniques, more instances can be solved. However, using dual proof analysis on top of conflict graph analysis does not lead to more solved instances, but one instance less being solved. Nevertheless, the consistently better running times of the `combined` setting lead us to the conclusion that an approach that conducts both techniques is preferable. Consequently, this is the default setting of FICO Xpress.

3.4.2 Presolving and Strengthening Techniques

To evaluate the computational impact within SCIP of the cancellation techniques described in Section 3.3.1.1 and the strengthening of dual proof constraints based on the incumbent solution described in Section 3.3.1.2, we disable both features and compare them to `combined`. In the following, we will refer to both variable cancellation strategies by `cancellation`, whereas the individual procedures using global variable bounds and variable bound constraints will be called `bound-cancellation` and `vbound-cancellation`, respectively. Moreover, we will refer to the strengthening step by `update`.

Variable Cancellation. `cancellation` affects 146 instances that can be solved by at least one setting, see Table 3.4. On these instances, our computational experiments indicate a slight performance improvement with respect to solving time of up to 3.5 % and a reduction in the tree size by up to 4.1 % gained by activating `cancellation`. The observed improvements gained by `cancellation` are small but consistent over all increasingly hard groups of affected instances. In our experiments, we observed a speedup (slowdown) of at least 5 % on 36 % (24 %) of the affected instances when `cancellation` is enabled. The number of rejections due to restrictions on the size of the support decreased by 73.6 % when `cancellation` is enabled.

Within `cancellation`, `bound-cancellation` and `vbound-cancellation` were successfully applied on roughly 3 % and 7 % of all analyzed infeasible LP relaxations.

Table 3.4: Aggregated computational results on instances affected by applying all cancellation techniques. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

		cancellation disabled			combined		
		S	**T**	**N**	**S**	**T_Q**	**N_Q**
all	714	345	1334	2939	344	0.996	0.987
affected	146	146	596	26544	145	0.983	0.971
$\geq$ 10	144	144	634	27961	143	0.983	0.967
$\geq$ 100	119	119	1135	48263	118	0.973	**0.949**
$\geq$ 1000	78	78	2313	152404	77	0.965	**0.939**

When only disabling `bound-cancellation`, 76 instances are affected. Note, in our implementation, nonzero variable cancellation with their global variable bounds is applied to continuous variables only. On the set of affected instances, using `bound-cancellation` improves the solving time by up to 6.2 %. The reduction of the tree size is up to 11.1 %.

Compared to `bound-cancellation`, deactivating `vbound-cancellation` affects 115 instances. When `vbound-cancellation` is enabled, the impact with respect to solving time is between 2.2 % (affected) and 4.1 % ("$\geq$ 1000"). Although we observe a minor reduction of solving time on the set of affected instances, `vbound-cancellation` reduces the tree size by 4.9 % to 8.7 %. Since `vbound-cancellation` substitutes continuous variables with variable bound constraints defined by general integer or binary variables, it is expected that the time spent for domain propagation slightly increases for these constraints. However, the modified dual proof constraints propagate better, i.e., lead to more additional variable bound deductions, since less continuous variables are involved.

In our implementation, `vbound-cancellation` is called before `bound-cancellation`. Consequently, every success of `vbound-cancellation` might have an immediate impact on the success rate of `bound-cancellation`. In our computational study, we observe that the success rate with respect to applied cancellations of the latter reduced by 15 % when `vbound-cancellation` is called first.

Updating Dual Proofs of Bound Exceeding LPs. Dual proof constraints derived from LP relaxations exceeding the current cutoff bound can be strengthened whenever a new incumbent solution is found. Enabling or disabling `update` affects 161 instances in our test set, see Table 3.5. The reduction of the solving time and tree size on the complete set of affected instances is neutral. On the set of hardest instances, `update` leads to a slowdown of 4.4 %. During the whole solving process `update` was applied to 35 % of all accepted dual proof constraints derived from a bound exceeding LP relaxation. In our experiments, we observed a speedup (slowdown) of at least 5 % on 31 % (29 %) of the affected instances when `update` is enabled.

Table 3.5: Aggregated computational results on instances affected by updating dual bound exceeding proofs. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

		update disabled			combined		
		S	**T**	**N**	**S**	**T_Q**	**N_Q**
all	715	347	1328	2875	345	1.001	0.995
affected	161	160	566	24587	158	1.005	0.990
$\geqslant 10$	160	159	580	24799	157	1.005	0.990
$\geqslant\geqslant 100$	136	135	932	40284	133	1.003	0.981
$\geqslant 1000$	80	79	2151	164409	77	1.044	1.035

In contrast to the previously discussed strengthening techniques, `update` explicitly incorporates the objective function and the cutoff bound. Thus, it is expected that this type of dual proof constraint works particularly well if the primal bound incrementally improves over time. On the other hand, if either a near-optimal solution is found right in the beginning or all solutions are found at the end of the tree search, `update` might have a negative impact on the overall solving process. Consequently, the impact of this strengthening technique strongly depends on the progress on the primal side. The better the solutions found early in the solving process, the less impact is expected from activating `update`.

3.4.3 Mixed Integer Rounding

To generate an alternative proof of infeasibility, we separate a c-MIR (see Section 3.3.2) inequality based on the dual proof constraint after applying the techniques discussed in Section 3.3.1. In the following, we will refer to this procedure as `mir-procedure`. To decide whether the additionally separated inequality should be accepted for further considerations its efficacy

$$\frac{b - a^\mathsf{T}\bar{x}}{\max\{0.000001, \|a\|_2\}}$$

with respect to the reference point $\bar{x}$ discussed in Section 3.3.2.2 is taken into account. A positive efficacy gives the normalized violation, otherwise the normalized redundancy. Thus, a larger efficacy is preferred. We only accept the separated inequality if the corresponding efficacy is larger than the efficacy of the dual proof constraint from which it was derived.

In our computational study, `mir-procedure` affects 70 instances, while reducing the solving time and tree size by 6.8 % and 3.9 %, respectively, see Table 3.6. Our computational results indicate that the harder the instances are, the more benefit is gained by applying `mir-procedure`. On the set of affected instances, `mir-procedure` is successfully applied to 12 % of all analyzed infeasible LP relaxations. In our experiments, we

Table 3.6: Aggregated computational results on instances affected by applying the c-MIR procedure. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

		`mir-procedure` disabled			`combined`		
		S	**T**	**N**	**S**	**T$_Q$**	**N$_Q$**
all	715	346	1335	2955	345	0.996	0.992
affected	70	69	1048	80192	68	**0.932**	0.961
$\geq$ 10	70	69	1048	80192	68	**0.932**	0.961
$\geq$ 100	63	62	1518	115304	61	**0.895**	**0.944**
$\geq$ 1000	50	49	2240	170987	48	**0.874**	**0.945**

observed a speedup (slowdown) of at least 5 % on 25 % (25 %) of the affected instances when `mir-procedure` is enabled.

3.4.4 Filtering

To distinguish between dual proof constraints that are expected to be promising in the remainder of the search and those that might lead to numerical troubles or an increase of the time spent during propagation, we apply a filtering step as described in Section 3.3.3. In the following, we refer to this step by `filtering`. Both filterings due to numerical conditions and size of the support are applied after all previously discussed techniques.

Our computational study indicates that `filtering` has the most significant impact among all presented techniques, see Table 3.7. `filtering` affects 135 instances and leads to a reduction of solving time and tree size by 4.5 % and 2.2 %, respectively, on these instances. The harder the instances are, the larger is the impact of `filtering`. On the group of hardest instances, the solving time can be reduced by 8.9 %. Moreover, it leads to 7 additionally solved instances. In our experiments, we observed a speedup (slowdown) of at least 5 % on 35 % (33 %) of the affected instances when `filtering` is enabled.

By applying `filtering`, 34 % of the dual proof constraints were rejected, where less than 1 % were rejected due to numerical properties, i.e., the ratio of the maximal and minimal nonzero coefficient in absolute value was larger than 1e+8. Thus, the most important filtering criterion is the size of the support. As described in Section 3.3.3, we consider the ratio of the average number of nonzeros of all maintained dual proof constraints and all model constraints.

3.4.5 Overall Impact of Techniques

In the previous paragraphs, we analyzed the individual impact of every technique discussed in this chapter. Table 3.8 shows the impact on the performance when disabling all techniques at the same time. On the subset of affected instances, we observe an

Table 3.7: Aggregated computational results on instances affected by filtering dual proofs. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

		filtering disabled			combined		
		S	**T**	**N**	**S**	**T_Q**	**N_Q**
all	715	338	1342	2748	345	0.991	0.992
affected	135	127	539	15415	134	0.955	0.978
≥ 10	134	126	555	15528	133	0.955	0.979
$\geq\geq 100$	107	99	1117	32614	106	**0.933**	**0.943**
≥ 1000	69	61	2581	111484	68	**0.911**	**0.940**

Table 3.8: Aggregated computational results on instances affected by deactivating all features. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

		all disabled			combined		
		S	**T**	**N**	**S**	**T_Q**	**N_Q**
all	715	345	1356	2866	345	0.980	0.961
affected	197	193	560	15757	193	**0.930**	**0.933**
≥ 10	194	190	598	16363	190	**0.929**	**0.932**
$\geq\geq 100$	162	158	1014	28174	158	**0.912**	**0.919**
≥ 1000	97	93	2376	115049	93	**0.889**	**0.908**

improvement of solving time by 7 % when enabling all features. On affected instances that could be solved by both settings, the tree size reduces by 6.7 %. When disabling all discussed features, the implementation corresponds to the one used in our preliminary study (Witzig et al., 2017).

3.5 Conclusion and Outlook

In this chapter, we studied the combination of conflict graph analysis and dual proof analysis for infeasible and bound exceeding LP relaxations within a single solver. Our computational results indicate that both improve the performance of MIP solvers, with conflict graph analysis being the more powerful technique. A combined approach performed best, for both solvers, SCIP and FICO Xpress, that we used for our experiments.

Furthermore, we introduced three enhancements for dual proof analysis: Presolving via variable cancellation, strengthening by applying mixed integer rounding functions, and a filtering mechanism. All of those enhancements led to clear performance improvements. A method to update bound-exceeding proofs, however, did not benefit the solver.

We conclude that infeasibility analysis plays an important role in the solution process of mixed integer programming problems, and that a combination of different techniques is worthwhile. The generalization of the presented methods towards mixed

integer nonlinear programming provides an interesting line for future research. The first results in this direction are discussed in Chapter 7.

Chapter 4

Conflict-Free Learning

Conflict learning plays an important role in solving mixed integer programs (MIPs) and is implemented in most major MIP solvers. A major step for MIP conflict learning is to aggregate the LP relaxation of an infeasible subproblem to a single globally valid constraint, the dual proof, that proves infeasibility within the local bounds. Among others, one way of learning is to add these constraints to the problem formulation for the remainder of the search.

In this chapter, we suggest to not restrict this procedure to infeasible subproblems, but to also use global proof constraints from subproblems that are not (yet) infeasible, but can be expected to be pruned soon. As a special case, we also consider learning from integer feasible LP solutions.

4.1 Introduction

In this chapter, we consider *mixed integer programs (MIPs)* of the form 2.1. Remember, a MIP of form (2.1) reads as

$$\min\{c^\mathsf{T} x \mid Ax \geq b,\ \ell \leq x \leq u,\ x_j \in \mathbb{Z}\ \forall j \in \mathcal{I}\},$$

with objective coefficient vector $c \in \mathbb{R}^n$, constraint coefficient matrix $A \in \mathbb{R}^{m \times n}$, constraint right-hand side $b \in \mathbb{R}^m$, and variable bounds $\ell, u \in \overline{\mathbb{R}}^n$, where $\overline{\mathbb{R}} := \mathbb{R} \cup \{\pm\infty\}$. Furthermore, let $\mathcal{N} = \{1, \ldots, n\}$ be the index set of all variables and let $\mathcal{I} \subseteq \mathcal{N}$ be the set of variables that need to be integral in every feasible solution. In contrast to the previous sections, we allow that the constraint right-hand side b can be tightened at any point in time to $\tilde{b} \in \mathbb{R}^m$ with $\bar{b} \geq \tilde{b} \geq b$ and $\bar{b} \in \overline{\mathbb{R}}^m$. Note, we say that $\tilde{b}$ is greater or equal to b, if $\tilde{b}_i \geq b_i$ for all $i = 1, \ldots, m$. An important special case of this general setting is the tightening of the so-called *cutoff bound* $\bar{c}$ during the MIP search.

The cutoff bound is either defined by the objective value of current incumbent, i.e., the currently best-known, solution $\overline{x}$ or $+\infty$ if no solution has been found yet. It gives rise to the *objective cutoff constraint*

$$-c^{\mathsf{T}}x \geq -\overline{c}. \tag{4.1}$$

The objective cutoff constraint (4.1) models an upper bound on all MIP solutions found in the remainder of the search. In the following, we assume that the objective cutoff constraint (4.1) is explicitly contained in $Ax \geq b$. The computational experiments of this chapter will focus on the case that the objective cutoff constraint is the only constraint being tightened during the search, the theoretical background, however, will be given for the general case $\overline{b} \geq \tilde{b} \geq b$.

As already discussed in Section 2.2, a lower bound on the MIP solution is given by its LP relaxation. In LP-based branch-and-bound (Dakin, 1965; Land and Doig, 1960) as described in Section 2.2 the LP relaxation is used for bounding. During this procedure, we may encounter infeasible subproblems. Infeasibility can be detected by contradicting implications, e.g., derived by domain propagation, by an infeasible LP relaxation, or an LP relaxation that exceeds the objective value of the current incumbent solution. Following our assumption that the objective cutoff constraint is part of the constraint matrix, the latter is just a special case of an infeasible LP relaxation.

Assume we are given an infeasible node of the branch-and-bound tree defined by the subproblem of form (2.6) which reads as

$$\min\{c^{\mathsf{T}}x \mid Ax \geq b,\ \ell' \leq x \leq u',\ x \in \mathbb{Z}^k \times \mathbb{R}^{n-k}\}$$

with local bounds $\ell \leq \ell' \leq u' \leq u$. Now, we can apply conflict analysis as described in Section 2.4 and Chapter 3. Remember, from every infeasible LP relaxation a dual proof constraint of form (2.11) which reads as

$$y^{\mathsf{T}}Ax \geq y^{\mathsf{T}}b$$

can be derived. This constraint has to be fulfilled by every feasible solution of the MIP.

Observation 21. *Let $b \in \mathbb{R}^m$ be the constraint right-hand side and $y^{\mathsf{T}}Ax \geq y^{\mathsf{T}}b$ be a dual proof constraint that was derived from some infeasible subproblem. If tightening the (global) constraint right-hand side to $\tilde{b} \in \mathbb{R}^m$ with $\overline{b} \geq \tilde{b} \geq b$ the following holds.*

(i) $y^{\mathsf{T}}Ax \geq y^{\mathsf{T}}b$ is still globally valid.

(ii) The dual proof can be strengthened to $y^{\mathsf{T}}Ax \geq y^{\mathsf{T}}\tilde{b}$, while preserving global validity.

4.2 LP-Based Solution Learning

Conflict-driven learning or no-good learning (Prosser, 1993; Zhang et al., 2001), is a fundamental concept in SAT and CP. Besides learning from infeasibility, the methodology of solution-driven learning or good-learning (Giunchiglia et al., 2003), i.e., learning from feasibility, has been applied in SAT and CP. Generally, algorithms for infeasibility learning can be extended to solution learning by pretending that the corresponding cutoff constraint with the updated incumbent was already present for the current subproblem and would prove it to be infeasible (after the incumbent update).

To the best of our knowledge, solution learning has not yet been studied for MIP. Every LP that yields an optimal solution that is MIP-feasible, i.e., feasible for (2.1), can be used to apply *LP-based solution learning*.

Consider a subproblem (2.6) with local bounds ℓ' and u'. Moreover, let $x^\star_{\text{LP}}$ be an optimal solution of its LP relaxation that is feasible for MIP (2.1). If $x^\star_{\text{LP}}$ is an improving solution, i.e., $c^\mathsf{T} x^\star_{\text{LP}} < \bar{c}$, $x^\star_{\text{LP}}$ defines the new incumbent solution. Consequently, the cutoff bound can be updated to

$$\bar{c} = c^\mathsf{T} x^\star_{\text{LP}} - \epsilon$$

with $\epsilon > 0$. Note that MIP solvers using floating point arithmetic typically subtract a small epsilon in the order of magnitude of the used tolerances, e.g., SCIP uses $\epsilon = 10^{-6}$, to enforce strict improvement during the search. If all variables with a non-zero coefficient in the objective function are integral, the minimal improvement in the objective value can be computed by a GCD-like algorithm and used as an epsilon. For example, the objective value always improves by a multiple of 1 if $c_j \in \{-1, 0, 1\}$ with $j \in \mathcal{I}$ and $c_j = 0$ with $j \in \mathcal{N} \setminus \mathcal{I}$. Thus, $\epsilon = 1$ could be used in this case.

Since the objective cutoff constraint (4.1) is part of the constraint matrix A, the constraint right-hand side b changes when updating the cutoff bound. Assume that row index k represents the matrix row associated to the objective cutoff constraint, i.e., $A_{k\cdot} x \geq b_k$ with $-c^\mathsf{T} = A_{k\cdot}$ and $b_k = -\bar{c}$. After an incumbent update, the right-hand side vector changes to $\tilde{b}$ with $\tilde{b}_k = b_k + \bar{c} - c^\mathsf{T} x^\star_{\text{LP}}$ and $\tilde{b}_i = b_i$ for all $i = 1, \ldots, m$ with $i \neq k$. Thus, the feasible LP relaxation defined by the local bounds ℓ' and u' turns infeasible after the update. Henceforth, we can apply both conflict graph analysis and dual proof analysis to learn from LP relaxations that yield integer feasible solutions.

4.2.1 Implementation

In our implementation, LP-based solution learning is applied whenever the LP relaxation yields a feasible solution, i.e., all integrality conditions are satisfied, that improved the incumbent solution. Note, in principle LP-based solution learning could also be ap-

plied for all improving solutions, e.g., found within a heuristic, with an objective value equal to the objective value of the LP relaxation. However, this is not considered in this publication and subject of future research.

Since solution learning can immediately be applied when the feasible LP relaxation turns into a bound exceeding LP both *conflict graph analysis* and *dual proof analysis* as described in Section 2.4.2 and Chapter 3 are applied in our implementation without introducing much computational overhead.

4.3 Conflict-Free Dual Proofs

State-of-the-art MIP solvers like SCIP and FICO XPRESS do not actively steer the tree seach towards the exploration of infeasible subproblems. Thus, learning from infeasibility information can be considered to be a "byproduct".

Here, we will discuss how the concept of conflict analysis can be extended to learn from subproblems that are not (yet) infeasible. Therefore, we consider dual proofs of form (2.11) that are *conflict-free*.

Definition 22 (Conflict-Free Dual Proof)**.** *Let $\ell \leq \ell' \leq u' \leq u$ be a set of local bounds and $y^\mathsf{T}Ax \geq y^\mathsf{T}b$ be an aggregation of globally valid constraint weighted by $y \in \mathbb{R}^m_{\geq 0}$. The inequality $y^\mathsf{T}Ax \geq y^\mathsf{T}b$ is called* conflict-free dual proof *with respect to ℓ' and u' if*

i) $\Delta_{\max}(y^\mathsf{T}A, \ell', u') \geq y^\mathsf{T}b$ *and*

ii) $\exists\, \tilde{b} \in \mathbb{R}$ *with* $\bar{b} \geq \tilde{b} \geq b$ *such that* $\Delta_{\max}(y^\mathsf{T}A, \ell', u') < y^\mathsf{T}\tilde{b}$.

Within a black-box MIP solver (e.g., SCIP, FICO XPRESS, GUROBI, and CPLEX) that considers the cutoff bound for pruning subproblems, the concept of conflict-free dual proofs simplifies as follows. Without loss of generality let $A_{m\cdot}x \geq b_m$ be the row assigned to the cutoff bound. Moreover, let $\hat{A} \in \mathbb{R}^{n\times(m-1)}$ be the coefficient matrix without the row assigned to the objective cutoff constraint (4.1) and $\hat{b} \in \mathbb{R}^{m-1}$ the corresponding constraint right-hand side, i.e.,

$$A := \begin{bmatrix} \hat{A} \\ -c \end{bmatrix} \quad \text{and} \quad b := \begin{bmatrix} \hat{b} \\ -\bar{c} \end{bmatrix}.$$

Let (y, r) be a dual feasible solution for (2.3) with respect to the local bounds ℓ' and

u'. From complementary slackness, it follows that $y_m = 0$. Thus, it holds that

$$\begin{aligned}
& c^\mathsf{T}\overline{x} \geq y^\mathsf{T}b + r^\mathsf{T}\{\ell', u'\} \\
\Leftrightarrow \quad & \overline{c} \geq y^\mathsf{T}b + (c - y^\mathsf{T}A)\{\ell', u'\} \\
\Leftrightarrow \quad & \overline{c} \geq \hat{y}^\mathsf{T}\hat{b} + y_m\overline{c} + (c - (\hat{y}^\mathsf{T}\hat{A} + y_m c))\{\ell', u'\} \\
\Leftrightarrow \quad & \overline{c} \geq \hat{y}^\mathsf{T}\hat{b} + (c - \hat{y}^\mathsf{T}\hat{A})\{\ell', u'\} \\
\Leftrightarrow \quad & (\hat{y}^\mathsf{T}\hat{A} - c)\{\ell', u'\} \geq \hat{y}^\mathsf{T}\hat{b} - \overline{c} \\
\Leftrightarrow \quad & y^\mathsf{T}A\{\ell', u'\} \geq y^\mathsf{T}b \quad \text{with } y_m = 1.
\end{aligned}$$

From every dual feasible solution $(y, r) \in \mathbb{R}^{m+n}$ a globally valid constraint

$$y^\mathsf{T}Ax \geq y^\mathsf{T}b \tag{4.2}$$

can be derived. This constraint is generally not violated with respect to ℓ, u and will not be violated with respect to ℓ' and u' either, when the local LP relaxation is feasible. Moreover, let $\underline{c} \in \overline{\mathbb{R}}$ be the current dual bound, i.e., the global lower bound on the MIP solution value. If there exists a $\tilde{c} \in \mathbb{R}$ with $\underline{c} < \tilde{c} < \overline{c}$ such that

$$(\hat{y}^\mathsf{T}\hat{A} - c)\{\ell', u'\} < \hat{y}^\mathsf{T}\hat{b} - \tilde{c},$$

then (4.2) is a *conflict-free dual proof*. The new global right-hand side is defined by $\tilde{b} := \left[b, -\tilde{c}\right]^\mathsf{T}$.

4.3.1 Implementation

In our implementation, we maintain a storage of conflict-free dual proofs which is restricted to at most 200 entries. For every conflict-free dual proof we calculate the *primal target bound* $\tilde{c} := \overline{c} + (\Delta_{\max}(y^\mathsf{T}A, \ell', u') - \hat{y}^\mathsf{T}b)$. The decision whether a conflict-free dual proof is added to the storage for later considerations only depends on the primal target bound. If the storage maintains less than 200 entries, a conflict-free dual proof is accepted if its primal target bound is at least the current global dual bound. In case of a completely filled storage, the newly derived conflict-free dual proof is immediately rejected if its primal target bound is smaller (i.e., worse) than the smallest target bound among all maintained conflict-free dual proofs. Otherwise, the conflict-free dual proof is accepted if it has a larger (i.e., better) target bound are less nonzero entries. With this strategy we aim to prefer short conflict-free dual proofs that tend to propagate earlier with respect to the cutoff bound, i.e., the improvements on the primal side. Whenever a new conflict-free dual proof is derived, all maintained conflict-free dual proofs whose primal target bound become worse than the global dual bound are

immediately removed from the storage.

If a new incumbent solution $\overline{x}$ is found, we add at most 10 conflict-free dual proofs for which $\tilde{c} \geq c^{\mathsf{T}}\overline{x}$ holds to the actual solving process, i.e., these (conflict-free) dual proofs become "active" and are considered during the remainder of the search for, e.g., variable bound propagation. Moreover, we allow for slight relaxed primal target bounds. Thus, every conflict-free dual proof for which $\tilde{c} \geq (1+\alpha)c^{\mathsf{T}}\overline{x}$, with $\alpha \geq 0$, holds is considered to become active. In our computational experiments we used $\alpha = 0.1$.

4.4 Computational Experiments

To evaluate the computational impact of the techniques presented in this chapter, we implemented LP-based solution learning and conflict-free learning within the academic MIP solver SCIP. In the following, we will refer to SCIP with default settings[1] as `default` and to SCIP with enabled LP-based solution learning and enabled conflict-free learning as `sollearning` and `conffree`, respectively. To SCIP using both techniques simultaneously will refer as `combined`.

All experiments are based on SCIP 6.0.2 using SOPLEX 4.0.2 as LP solver (Gleixner et al., 2017). The experiments were run on a cluster of identical machines equipped with Intel Xeon E5-2690 CPUs with 2.6 GHz and 128 GB of RAM. A time limit of 7200 seconds was set. To evaluate the generated performance data the *interactive performance evaluation tool*[2] (IPET) was used.

As test set we used the benchmark set of MIPLIB 2017[3] which consists of 240 MIP problems. To account for the effect of performance variability (Koch et al., 2011; Lodi and Tramontani, 2013) all experiments were performed with three different global random seeds. Determinism is preserved because SCIP uses pseudo-random number generators only. Every pair of MIP problem and seed is treated as an individual observation, effectively resulting in a test set of 720 instances. We will use the term "instance" when referring to a problem-seed combination. Instances where at least one setting finished with numerical violations are not considered in the following.

Aggregated results on MIPLIB 2017 comparing all three configurations to SCIP with default settings as baseline are shown in Table 4.1. Next to MIPLIB 2017, the comparison is divided into the set of instances were no general integer variable is present after presolving (MIXED BINARY) and its complement (GENERAL INTEGER). For every set of instances the group of affected instances is shown. We denote an instance to be affected, if it could be solved at least one setting and if the number of nodes explored during the tree search differs among settings. Moreover, the subset of hard instances that are affected is shown ($\geq$ 100). The columns of Table 4.1 show the number of

[1] The default contains the techniques discussed in Chapter 3.
[2] https://github.com/GregorCH/ipet
[3] http://miplib.zib.de

instances in every groups (#) and the number of solved instances (**S**). For the baseline (`default`) the shifted geometric mean as defined in (2.13) of solving times in seconds (**T**, shift = 1) and explored search tree nodes (**N**, shift = 100) is shown. For `conffree`, `sollearning`, and `combined` relative solving times ($\mathbf{T_Q}$) and nodes ($\mathbf{N_Q}$) compared to `default` are shown. Relative numbers less than 1 indicate improvements.

Our computational experiments indicate, that both individual techniques and the combination of them are superior compared to `default`. On affected instances, we observe an overall speed up of 3 % (`sollearning`) on the complete test set. At the same time, the tree size reduced by up to 10 % (`combined`) on the same set of instances. Regarding solving time and tree size, `sollearning` is superior to `conffree`. `combined` is superior to both individual settings regarding nodes and almost identical to `sollearning` regarding solving time.

A reason why `conffree` seems to be less powerful than `sollearning` might be the fact that dual proof constraints are known to work better in the neighborhood of the subproblem where they were derived from (Achterberg, 2016), which is usually controlled by maintaining a small pool of around 100 dual proof constraints as we have discussed in Section 3.2. In our implementation, the origin of conflict-free dual proofs is not considered. Thus, considering the origin of conflict-free dual proof constraints when deciding which should become "active" or considering them only locally might be worthwhile.

`sollearning` is only applied when to feasible LP relaxation providing an improving solution. Hence, the time spent during conflict analysis per node only increases by 2.4 % on affected instances. Compared to that, `conffree` applies dual proof analysis for every feasible LP relaxation. Consequently, we observe a increase a factor of 3.4 on the same set of instances.

In our computational study we observed, that `sollearning` performs worse on General Integer, i.e., instances containing general integer variables after presolving. One reason for the deterioration might be that `sollearning` applies conflict graph analysis. Whenever a general integer variable is present in the set of conflicting literals, SCIP generates bound disjunction constraints Achterberg (2007a) which do not have a linear representation. Since SCIP pursues a pool-based approach to maintain conflict constraints (see Section 3.2) adding bound disjunction constraints lead to discarding constraints with a linear representation that might lead to more variable bound deductions.

4.5 Conclusion and Outlook

In this chapter, we discussed how conflict analysis techniques can be applied to learn from subproblems that are not (yet) proven to be infeasible. For our computational

Table 4.1: Aggregated computational results on MIPLIB 2017 benchmark over three random seeds. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

		default			conffree			sollearning			combined		
	#	S	T	N	S	T_Q	N_Q	S	T_Q	N_Q	S	T_Q	N_Q
MIPLIB 2017													
all	716	369	1124	6069	370	1.001	0.976	368	0.995	0.991	368	1.000	0.973
affected	127	122	567	30265	123	0.993	**0.927**	121	0.975	0.952	121	0.987	**0.902**
≥ 100	107	102	969	45972	103	0.987	**0.919**	101	0.970	**0.944**	101	0.979	**0.887**
MIXED BINARY													
all	523	272	1153	5639	273	1.000	0.976	272	0.991	0.983	273	0.996	0.967
affected	83	81	517	26406	82	0.983	**0.913**	81	**0.943**	**0.901**	82	0.958	**0.857**
≥ 100	72	70	817	42289	71	0.973	**0.899**	70	**0.934**	**0.886**	71	**0.942**	**0.834**
GENERAL INTEGER													
all	193	97	1050	7405	97	1.005	0.977	96	1.008	1.013	95	1.013	0.988
affected	44	41	674	39140	41	1.011	0.954	40	1.038	*1.055*	39	1.046	0.991
≥ 100	35	32	1376	54587	32	1.017	0.963	31	1.047	*1.075*	30	*1.058*	1.007

study, we implemented two conflict-free learning techniques, namely conflict-free dual proofs and LP-based solution learning, within the academic MIP solver SCIP. The results of our study indicate promising results on the benchmark set of MIPLIB 2017 when applying conflict-free learning techniques within SCIP. We observed that the time spent for applying conflict analysis techniques increased by a factor of 3.4 when applying conflict-free learning. Moreover, our experiments indicate that solution learning seem to work best on mixed binary instances.

Applying machine learning techniques to predict from which not (yet) infeasible subproblems conflict-free dual proofs should be derived and considering the locality of derived proofs is aimed to be future research.

Chapter 5

Local Rapid Learning for Integer Programms

Conflict learning algorithms are an important component of modern MIP and CP solvers. But strong conflict information is typically gained by depth-first search. While this is the natural mode for CP solving, it is not for MIP solving. Rapid Learning is a hybrid CP/MIP approach where CP search is applied at the root to learn information to support the remaining MIP solve. This has been demonstrated to be beneficial for binary programs. In this chapter, we extend the idea of Rapid Learning to integer programs, where not all variables are restricted to the domain $\{0, 1\}$, and rather than just running a rapid CP search at the root, we will apply it repeatedly at local search nodes within the MIP search tree. To do so efficiently, we present six heuristic criteria to predict the chance for local Rapid Learning to be successful.

5.1 Introduction

Constraint programming (CP) and integer programming (IP) are two complementary ways of tackling discrete optimization problems. Hybrid combinations of the two approaches have been used for many years, see, e.g., Achterberg (2007b); Althaus et al. (2002); Aron et al. (2004); Bockmayr and Kasper (1998); Rodosek et al. (1999); Yunes et al. (2010); Davies et al. (2017). Both technologies have incorporated *conflict learning* capabilities (Davey et al., 2002; Katsirelos and Bacchus, 2005; Sandholm and Shields, 2006; Achterberg, 2007a; Ohrimenko et al., 2009) that derive additional valid constraints from the analysis of infeasible subproblems extending methods developed by the SAT community (Moskewicz et al., 2001).

Conflict learning is a technique that analyzes infeasible subproblems encountered during a tree search algorithm. In a tree search, each subproblem can be identified

by its local variable bounds, i.e., by local bound changes that come from branching decisions and propagation at the current node and its ancestors. If propagation detects infeasibility, conflict learning will traverse this chain of decisions and deductions reversely, reconstructing which bound changes led to which other bound changes. In this way, conflict learning identifies explanations for the infeasibility. If it can be shown that a small subset of the bound changes suffices to prove infeasibility, a so-called conflict constraint is generated that can be exploited in the remainder of the search to prune parts of the tree.

In the context of constraint programming, conflict constraints are also referred to as *no-goods*. For binary programs (BPs), i.e., mixed integer (linear) programs for which all variables have domain $\{0, 1\}$, conflict constraints will have the form of *set covering* constraints. These are linear constraints of the form "sum of variables (or their negated form) is greater than or equal to one".

RAPID LEARNING (Berthold et al., 2010) is a heuristic algorithm for BPs that searches for valid conflict constraints, global bound reductions, and primal solutions. It is based on the observation that a CP solver can typically perform an incomplete search on a few thousand nodes in a fraction of the time that a MIP solver needs for processing the root node. In addition, CP solvers make use of depth-first search, as opposed to the hybrid best-first/depth-first search of MIP solvers, which more rapidly generates strong no-goods. Typically CP solvers do not differentiate the root node from other nodes. They apply fast (at least typically) propagation algorithms to infer new information about the possible values variables can take, and then take branching decisions. In contrast, a MIP solver invests a substantial amount of time at the root node to gather global information about the problem and to initialize statistics that can help for the search. A significant portion of root node processing time comes from the computational effort needed to solve the initial LP relaxation from scratch. Further aspects are the LP resolves during cutting plane generation, strong branching (Achterberg et al., 2005) for branching statistic evaluation, and primal heuristics, see, e.g., Berthold (2014a).

The idea of RAPID LEARNING is to apply a fast CP depth-first branch-and-bound search for a few hundred or thousand nodes, generating and collecting valid conflict constraints at the root node of a MIP search. Using this, the MIP solver is already equipped with the valuable information of which bound changes will lead to an infeasibility, and can avoid them by propagating the derived constraints. Just as important, the partial CP search might find primal solutions, thereby acting as a primal heuristic. Furthermore, the knowledge of conflict constraints can be used to initialize branching statistics, just like strong branching. In this chapter, we will extend RAPID LEARNING to integer programs and to nodes beyond the root.

The remainder of the chapter is organized as follows. In Section 5.2, we describe details of the RAPID LEARNING algorithm for general integer programs, extending the

work of Berthold et al. (2010). In Section 5.3, we discuss what special considerations have to be taken when applying Rapid Learning repeatedly at local subproblems during the MIP tree search instead of using it as a onetime global procedure. We introduce six criteria to predict the benefit of local Rapid Learning. Section 5.4 presents our computational study, in which we apply our extended Rapid Learning algorithm to a set of integer programs from the well-known benchmark sets of Miplib 3, Miplib 2003, and Miplib 2010 (Koch et al., 2011). The experiments have been conducted with the constraint integer programming solver SCIP (Gleixner et al., 2018) and indicate that a significant speed-up can be achieved for (pure) integer programs, when using Rapid Learning locally. In Section 5.5, we conclude.

5.2 Rapid Learning for Integer Programs

The principle motivation for Rapid Learning (Berthold et al., 2010) is the fact that a CP solver can typically search hundreds or thousand of nodes in a fraction of the time that a MIP solver needs for processing the root node of the search tree. Rapid Learning applies a fast CP search[1] for a few hundred or thousand nodes, before starting the MIP search. Using this approach, conflict constraints can be learnt before, and not only during, MIP search. Very loosely speaking: while the aim of conflict learning is to avoid making mistakes a second time, Rapid Learning tries to avoid making them the first time (during MIP search).

Rapid Learning is related to large neighborhood search heuristics, such as Rins and Rens (Berthold, 2014b; Danna et al., 2004). But, rather than doing an incomplete search on a subproblem using the same (MIP search) algorithm, Rapid Learning performs an incomplete search on the same problem using a much faster algorithm (CP search). Rapid Learning differs from primal heuristics in that it aims at improving the dual bound by collecting information on infeasibility rather than searching for feasible solutions.

Each piece of information collected in a rapid CP search can be used to guide the MIP search or even deduce further reductions during root node processing. Since the CP solver is solving the same problem as the MIP solver

- each generated conflict constraint is valid for the MIP search,
- each global bound change can be applied at the MIP root node,
- each feasible solution can be added to the MIP solver's solution pool,
- the branching statistics can initialize a hybrid MIP branching rule, see Achterberg and Berthold (2009), and

[1] By CP search we mean applying a depth-first search using only propagation for reasoning, no LP relaxation is solved during the search.

- if the CP solver completely solves the problem, the MIP solver can abort.

All five types of information may be beneficial for a MIP solver, and are potentially generated by our algorithm which we now describe more formally.

The RAPID LEARNING algorithm is outlined in Algorithm 1. Here, $\ell(\mathcal{P})$ and $u(\mathcal{P})$ are lower and upper bound vectors, respectively, of the problem at hand, P. For the moment we assume P is the root problem, in the next section we will examine the use of RAPID LEARNING at subproblem nodes. The symbol C refers to a single globally valid conflict constraint explaining the infeasibility of the current subproblem. RAPID LEARNING is an incomplete CP search: a branch-and-bound algorithm which traverses the search space in a depth-first manner (Line 3), using propagation (Line 4) and conflict analysis (Line 7), but no LP relaxation. Instead, the *pseudo-solution* (Achterberg, 2007b), i.e., an optimal solution of a relaxation consisting only of the variable bounds (Line 5), is used for the bounding step.

Propagation of linear constraints is conducted by the bound strengthening technique of Brearley et al. (1975) which uses the residual activity of linear constraints within the local bounds. For special cases of linear constraints, SCIP implements special, more efficient propagators. Knapsack constraints use efficient integer arithmetic instead of floating point arithmetic, and sort by coefficient values to propagate each variable only once. SCIP also features methods to extract clique information about the binary variables of a problem. A clique is a set of binary variables of which at most one variable can take the value 1 in a feasible solution. Clique information can be used to strengthen the propagation of knapsack constraints. Set cover constraints are propagated by the highly efficient two-watched literal scheme (Moskewicz et al., 2001), which is based on the fact that the only domain reduction to be inferred from a set cover constraint is to fix a variable to 1 if all other variables have already been fixed to 0.

Variable and value selection takes place in Line 14; inference branching (Achterberg, 2007b) is used as branching rule. Inference branching maintains statistics about how often the fixing of a variable led to fixings of other variables, i.e., it is a history rule, it is essentially a MIP equivalent of impact-based search (Li and Anbulagan, 1997; Refalo, 2004). Since history rules are often weak in the beginning of the search, we seed the CP solver with statistics that the MIP solver has collected in probing (Savelsbergh, 1994) during MIP presolving.

We assume that the propagation routines in Line 4 may also deduce global bound changes and modify the global bound vectors $\ell(\mathcal{P})$ and $u(\mathcal{P})$. Single-clause conflicts are automatically upgraded to global bound changes in Line 9. Note that it suffices to check constraint feasibility in Line 11, since the pseudo-solution $\bar{x}$ (see Line 5) will always take the value of one of the (integral) bounds for each variable.

Our implementation of the RAPID LEARNING heuristic uses a secondary SCIP instance to perform the CP search. Only a few parameters need to be altered from their

Algorithm 1: Rapid Learning Algorithm

Input : IP $\mathcal{P}$ as in (2.1) node limit $\lim_{\text{node}}$,
primal bound $\bar{c}$ for $\mathcal{P}$ (might be ∞)

Output: set of valid conflict constraints $\mathcal{L}_C$ for $\mathcal{P}$,
valid global domain box $[\ell, u]$ for $\mathcal{P}$,
feasible solution $\tilde{x}$ for $\mathcal{P}$ or $\emptyset$

$\mathcal{L} \leftarrow \{\mathcal{P}\}$, $\mathrm{n}_{\text{node}} \leftarrow 0$, $\mathcal{L}_C \leftarrow \emptyset$, $\tilde{x} \leftarrow \emptyset$
while $\mathcal{L} \neq \emptyset \wedge \mathrm{n}_{\text{node}} < \lim_{\text{node}}$ **do**
  $\mathcal{P}' \leftarrow$ `select_dfs(`$\mathcal{L}$`)`, $\mathcal{L} \leftarrow \mathcal{L} \setminus \mathcal{P}'$, $\mathrm{n}_{\text{node}} \leftarrow \mathrm{n}_{\text{node}} + 1$
  $[\ell(\mathcal{P}'), u(\mathcal{P}')] \leftarrow$ `propagate(`$[\ell(\mathcal{P}'), u(\mathcal{P}')]$`)`
  $\bar{x} \leftarrow \operatorname{argmin}\{c^{\mathsf{T}} x \mid x \in [\ell(\mathcal{P}'), u(\mathcal{P}')]\}$

  `/* analyze infeasible subproblem, potentially store globally valid conflict constraint */`
  if $[\ell(\mathcal{P}'), u(\mathcal{P}')] = \emptyset$ **or** $c(\bar{x}) \geq \bar{c}$ **then**
    $C \leftarrow$ `analyze(`$\mathcal{P}'$`)`
    if $C \neq \emptyset$ **then** $\mathcal{L}_C \leftarrow \mathcal{L}_C \cup \{C\}$
    if $|C| = 1$ **then** `tighten(`$[\ell(\mathcal{P}), u(\mathcal{P})]$`)`
    continue

  `/* check for new incumbent solution */`
  if $A\bar{x} \leq b$ **and** $c^T \bar{x} < \bar{c}$ **then**
    $\tilde{x} \leftarrow \bar{x}$, $\bar{c} \leftarrow c^T \bar{x}$
    continue

  $(x_i, v) \leftarrow$ `select_infer(`$\mathcal{P}'$, $\bar{x}$`)`
  $\mathcal{P}'_l \leftarrow \mathcal{P}' \cup \{x_i \leq v\}$, $\mathcal{P}'_r \leftarrow \mathcal{P}' \cup \{x_i \geq v\}$
  $\mathcal{L} \leftarrow \mathcal{L} \cup \{\mathcal{P}'_l, \mathcal{P}'_r\}$
return $(\mathcal{L}_C, [\ell(\mathcal{P}), u(\mathcal{P})], \tilde{x})$

Table 5.1: Settings for Rapid Learning sub-SCIP.

parameter name	value	effect
lp/solvefreq	-1	disable LP
conflict/fuiplevels	1	use 1-UIP
nodeselection/dfs/stdpriority	INT_MAX/4	use DFS
branching/inference/useweightedsum	FALSE	pure inference, no VSIDS
constraints/disableenfops	TRUE	no extra checks
propagating/pseudoobj/freq	-1	no objective propagation
conflict/maxvarsfac	0.05	only short conflicts
history/valuebased	TRUE	extensive branch. statistics

default values to turn SCIP into a CP solver, an overview is given in Table 5.1. Most importantly, we disabled the LP relaxation and use a pure depth-first search with inference branching (but without any additional tie breakers). Further, we switch from All-UIP to 1-UIP in order to generate only one conflict per infeasibility. This is a typical behavior of CP solvers, but not for MIP solvers. Expensive feasibility checks and propagation of the objective function as a constraint are also avoided.

In order to avoid spending too much time in RAPID LEARNING, the number of nodes explored during the CP search is limited to at most 5000. The actual number of allowed nodes is determined by the number of simplex iterations iter_{LP} performed so far in the main SCIP but at least 500, i.e.,

$$\text{lim}_{\text{node}} = \min\{5000, \max\{500, \text{iter}_{\text{LP}}\}\}.$$

The idea is to restrict RAPID LEARNING more rigorously for problems where processing of a single MIP node is cheap already. The number of simplex iterations is a deterministic estimate for node processing cost.

We aim to generate short conflict constraints, since these are most likely to frequently trigger propagations in the upcoming MIP search. Thus, we only collect conflicts that contain at most 5 % of the problem variables. Finally, we adapt the collection of branching statistics such that history information on general integer variables are collected per value in the domain rather than having one counter for down- and one for up-branches regardless of the value on which was branched. This can be essential for performing an efficient CP search on general integer variables, and was a building block that enabled us to use RAPID LEARNING on IPs rather than solely on BPs, as in Berthold et al. (2010).

In addition to the particular parameters listed in Table 5.1, we set the emphasis[2] for presolving to "fast". Emphasis settings for cutting are not necessary, since no LP relaxation is solved, from the armada of primal heuristics only a few are applied that do not require an LP relaxation, see Achterberg et al. (2012). Note that since RAPID LEARNING will be called at the end of the MIP root node, or even locally, see next Section, the problem that the CP solver considers has already been presolved, might contain cutting planes as additional linear constraints and have an objective cutoff constraint if a primal solution has been found by a primal heuristic during root node processing.

[2] In SCIP, emphasis settings correspond to a group of individual parameters being changed.

5.3 Local Rapid Learning

The original Rapid Learning algorithm (Berthold et al., 2010) was used as part of a root preprocessing, i.e., for every instance it was run exactly once at the end of the root node. But only running Rapid Learning at the root limits its effectiveness. We now discuss the factors that arise when we allow Rapid Learning to be run at local nodes inside the search tree

When running in the root only all information returned by the CP solver is globally valid, and the overhead to maintain the information gathered by Rapid Learning is negligible (Berthold et al., 2010). In contrast, when applying Rapid Learning at a local node within the tree conflicts and bound changes will only be locally valid in general. Since Rapid Learning uses a secondary SCIP instance to perform the CP search, all local information of the current node becomes part of the initial problem formulation for the CP search. Thus, conflicts gathered by Rapid Learning do not include bound changes made along the path from the root to the current node, they are simply considered as valid for this local node. As a consequence, these conflicts will only be locally valid and hence only applied to the current node of the MIP search. Using an assumption interface (Nadel and Ryvchin, 2012), local conflicts could be lifted to be globally valid. However, this is subject to future investigation and not considered in the current implementation of Rapid Learning.

In practice, all local information needs to be maintained when switching from one node of the tree to another. In CP solvers, switching nodes is typically very cheap, because depth-first search is used. However, a MIP solver frequently "jumps" within the tree. Therefore, two consecutively processed nodes can be quite different. In what follows, we will refer to the time spent for moving from one node to another node as *switching time*. The switching time can be used as an indicator to quantify the overhead introduced by all locally added information found by Rapid Learning.

To ensure that the amount of locally added information does not increase the switching time too much, we apply Rapid Learning very rarely by using an exponentially decreasing frequency of execution. Rapid Learning is executed at every node of depth d with

$$\log_\beta(d/f) \in \mathbb{Z}, \tag{5.1}$$

where β and f are two parameters to control the speed of decrease. For example, if $\beta = 1$ Rapid Learning is executed at every depth $d = i \cdot f$ with $i \in \mathbb{Z}_{\geq 0}$.

Unfortunately, the amount of locally valid information produced by Rapid Learning still leads to an increase of switching time by 21 %. Consequently, the overall performance decreased by 20 % in our first experiments. At the same time the number of explored branch-and-bound nodes decreased by 16 %. This indicates the potential

gains possible using local RAPID LEARNING.

To control at which subproblem RAPID LEARNING is applied we propose six criteria to forecast the potential of RAPID LEARNING. These criteria aim at identifying one of two situations. The first is to estimate whether the (sub)problem is infeasible or a pure feasibility problem. In these cases propagating conflicts is expected to be particularly beneficial. The second is to estimate the dual degeneracy of a problem. In this case, VSIDS branching statistics are expected to be particularly beneficial. The VSIDS (Marques-Silva and Sakallah, 1999) (variable state independent decaying sum) statistics takes the contribution of every variable (and its negated complement) in conflict constraints found so far into account. For every variable, the number of clauses (in MIP speaking: conflict constraints) the variable is part of is counted. In the remainder of the search the VSIDS are periodically scaled by a predefined constant. By this, the weight of older clauses is reduced over time and more recent observations have a bigger impact.

A basic solution of an LP is called *dual degenerate*, when it has nonbasic variables with zero reduced costs. One can define the dual degeneracy of a MIP as the average number of nonbasic variables with zero reduced costs appearing in a basic solution of its LP relaxation. The higher the dual degeneracy, the higher the chance that the LP objective will not change by branching and hence many of the costs involved in the pseudo-cost computation are zero. Therefore, for highly dual degenerate problems, using other branching criteria, such as VSIDS or inference scores, is crucial for solving the problem.

We now describe the six criteria we use to identify infeasible or dual degenerate problems, already using the criteria abbreviations from the tables in Section 5.4:

Criterion I: Dual Bound Improvement. During the tree search a valid lower bound for each individual subproblem is given by the respective LP solution. A globally valid lower bound is given by the minimum over all individual lower bounds. This global bound is called the *dual bound*. If the dual bound has not changed after processing a certain number of nodes, i.e., the dual bound is equal to the lower bound of the root node, it might be the case that the MIP lies inside a level plane of the objective, i.e., all feasible LP (and MIP) solutions will have the same objective. In other words, the instance might be a feasibility instance for which RAPID LEARNING was already shown to be very successful (Berthold et al., 2010). Feasibility instances are typically highly dual degenerate. The `dualbound` criterion means to call local RAPID LEARNING if the dual bound never changed during the MIP search.

Criterion II: Leaves Pruned by Infeasibility or Exceeding the Cutoff bound. During the tree search every leaf node either provides a new incumbent solution (the rare case), is proven to be infeasible or to exceed the current cutoff bound which is

given by the incumbent solution. The ratio of the latter two cases is used in SCIP's default branching rule. *Hybrid branching* (Achterberg and Berthold, 2009) combines pseudo-costs, inference scores, and conflict information into one single branching score. The current implementation in SCIP puts a higher weight on conflict information, e.g., VSIDS (Marques-Silva and Sakallah, 1999), and a lower weight on pseudo-costs when the ratio of infeasible and cutoff nodes is larger than a predefined threshold. The `leaves` criterion means to call local Rapid Learning if the ratio of infeasible leaves over those exceeding the cutoff bound is larger than 10. The rationale is that we expect (local) conflicts to be most beneficial, when infeasibility detection appears to be the main driver for pruning the tree.

Criterion III: LP Degeneracy. As mentioned above, the more nonbasic variables are dual degenerate, the less information can be gained during strong branching or pseudo-cost computation. As a consequence, Gamrath et al. (2020) introduced a modification to strong branching that considers the dual degeneracy of the LP solution. In rough terms, if either the share of dual degenerate nonbasic variables or the variable-constraint ratio of the optimal face exceed certain thresholds, strong branching will be deactivated. We adapt this idea of using the dual degeneracy of the current LP solution. The `degeneracy` criterion means to call local Rapid Learning if more than 80 % of the nonbasic variables are degenerate or the variable-constraint ratio of the optimal face is larger than 2, as proposed in Gamrath et al. (2020). In both cases we expect that "strong conflict generation" will be useful.

Criterion IV: (Local) Objective Function. If all variables with non-zero objective coefficients are fixed at the local subproblem, i.e., the objective is constant, Criteria I and II will apply: every LP solution is fully dual degenerate and the only possibility to prune a leaf node is by infeasibility. If there are only very few unfixed variables with nonzero objective are left, the criteria might not apply. However, it is likely that the targeted situations occur frequently in the tree rooted at the current subproblem, at the latest, when all the variables occurring in the objective are fixed. The `obj` criterion means to call local Rapid Learning once the objective support is small enough, in anticipation of the current subproblem turning into a feasibility problem. In our implementation we apply this criterion very conservatively, and call Rapid Learning only if the local objective is zero.

Criterion V: Number of Solutions. The most obvious evidence, and indeed a necessary one, that a MIP instance is infeasible, is that no feasible solution has been found during the course of the MIP search. Note that for most (feasible) MIP instances, primal heuristics find a feasible solution at the root node (Berthold, 2014a) or at the

latest during the first dive in the branch-and-bound. The `nsols` criterion means to call local RAPID LEARNING if no feasible solution has been found so far.

Criterion VI: Strong Branching Improvements. In the beginning of the tree search it is very unlikely that enough leaf nodes are explored to reliably guess whether the actual MIP is a feasibility instance. Therefore, we consider the subproblems evaluated during strong branching, which are concentrated at the top of the search tree. Similarly to Criterion II, we compute the ratio between the number of strong branching problems that gave no improvement in the objective or went infeasible to the number of strong branching problems where we observed an objective change. The `sblps` criterion means to call local RAPID LEARNING if this ratio exceeds a threshold of 10, hence strong branching does not appear to be efficient for generating pseudo-cost information.

In addition to the exponentially decreasing frequency and the six criteria above, we applied the following three changes to the original implementation of RAPID LEARNING used in Berthold et al. (2010).

- We limited the number of conflict constraints transferred from RAPID LEARNING back to the original search tree to ten. This corresponds to the SCIP parameter `conflict/maxconss` for the maximal allowed number of added conflicts per call of conflict analysis. We greedily use the shortest conflicts.
- We prefer conflict constraints that have a linear representation over bound disjunction constraints of form (2.8).
- To exploit performance variability (Danna, 2008; Lodi and Tramontani, 2013) every CP search is initialized with a different pseudo-random seed.

5.4 Computational Results

To evaluate how local RAPID LEARNING impacts IP solving performance, we used the academic constraint integer programming solver SCIP 6.0 (Gleixner et al., 2018) (with SOPLEX 4.0 as LP solver) and extended the existing code of RAPID LEARNING. The original implementation of RAPID LEARNING was already shown to significantly improve the performance of SCIP 1.2.0.5 on pure binary instances (Berthold et al., 2010). In this setting, RAPID LEARNING was applied exactly once at the root node. However, during the last eight years, SCIP has changed in many places. In SCIP 6.0, RAPID LEARNING is deactivated by default, since it led to a big performance variability.

Therefore, we use SCIP without RAPID LEARNING (as it is the current default) as a baseline. We will refer to this setting as `default`. In our computational experiments we evaluate the impact of local RAPID LEARNING if one or more of the criteria described in Section 5.3 are fulfilled. In the following, we will refer to the criteria I–VI as `dualbound`,

`leaves`, `degeneracy`, `obj`, `nsols`, and `sblps`, respectively. Within the tree, Rapid Learning is applied with an exponentially decreasing frequency (see Section 5.3). In our experiments, we used $f = 5$ and $\beta = 4$, i.e., Rapid Learning is called at depths d with $\log_4(d/5) \in \mathbb{Z}$, i.e., $d = 0, 5, 20, 80, 320 \ldots$, if one of the six criteria is fulfilled.

As a test set we used all pure integer problems of Miplib 3 (Bixby et al., 1998), Miplib 2003 (Achterberg et al., 2006) and the Miplib 2010 (Koch et al., 2011) benchmark set. This test set consists of 71 publicly available instances, which we will refer to as `MMM-IP`. The experiments were run on a cluster of identical machines, each with an Intel Xeon E5-2690 with 2.6 GHz and 128 GB of RAM; a time limit of 3600 seconds was set. To account for the effect of performance variability (Lodi and Tramontani, 2013) all experiments were performed with five different global random seeds.

In a first experiment we evaluated the efficacy of each individual criterion and global Rapid Learning as published in Berthold et al. (2010). Aggregated results are shown in Table 5.2, Section Exp.1. For detailed results we refer to Table C.1 in Appendix C. For every setting, the table shows the number of solved instances out of 355 (**S**), shifted geometric means as defined in (2.13) of the absolute solving time in seconds (**T**, shift = 1) and number of explored nodes (**N**, shift = 100), as well as the relative solving time ($\mathbf{T_Q}$) and number of nodes ($\mathbf{N_Q}$) with respect to `default` as a baseline.

Local Rapid Learning without any of the presented criteria (`nochecks`) leads to a performance decrease of 21 % on the complete test set `MMM-IP` compared to `default`. Always applying Rapid Learning only at the root (`onlyroot`), which corresponds to Rapid Learning as published in (Berthold et al., 2010), leads to slowdown of 10 % but solves one instance more. For this settings, we could observe a performance decrease of 29 % on the group of instances that are not affected[3] by Rapid Learning. To avoid a computational overhead and performance variability on instances where Rapid Learning is not expected to be beneficial, we apply the criteria `degeneracy`, `obj`, and `nsols` at the root node, too. Afterwards, the performance decrease of global Rapid Learning reduced to 3 %. The computational results indicate that almost all individual criteria are useful on their own. The solving time and generated nodes can be reduced by up to 7 % and 14 %, respectively, on the complete test set of 355. The exception is the `obj` criterion, which leads to a slowdown of 2 %, but solves one more instance than `default`. On the group of affected instances the solving time can be reduced by up to 21 %, using the `leaves` criterion. The number of generated nodes can be reduced by up to 39 % (for `degeneracy`) on the same group of instances.

The impact of the individual criteria on the solving time is illustrated in Figure 5.1. For each criterion, the box plot (McGill et al., 1978) shows the median (dashed line), and the 1st and 3rd quartile (shaded box) of all observations. For all criteria the median time ratio is at most one; only for `degeneracy` and `leaves` the median is strictly smaller

[3] An instance is called affected when the solving path changes.

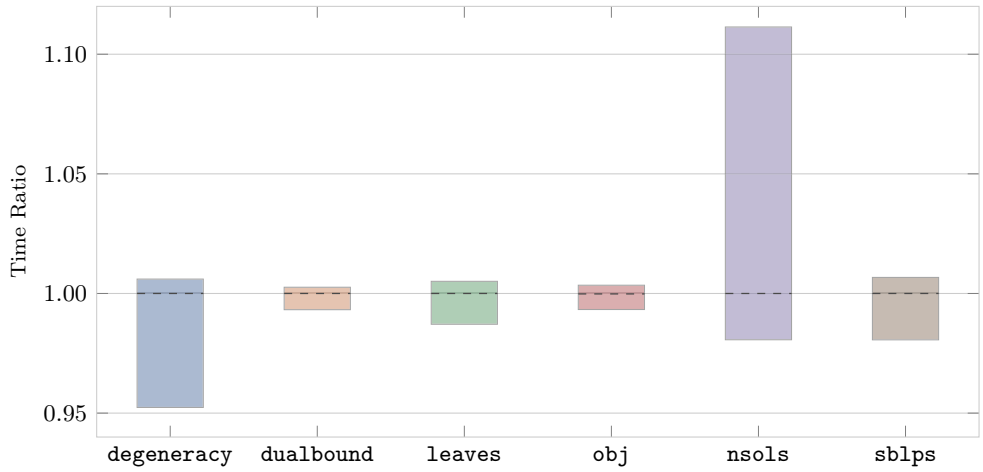


Figure 5.1: Box-plot of the performance ratios of the individual criteria compared to `default` on the set of affected instances.

than one. Hence, these two settings improve the performance on more than 50 % of the affected instances. Furthermore, `degeneracy` and `leaves` have by far the smallest 1st and 3rd quartile, indicating that the corresponding settings often improve performance and rarely deteriorate it.

Grouping all instances of `MMM-IP` based on the degeneracy at the end of the root node shows the importance of this criterion. On the group of instances where at least 1 % of the variables is dual degenerate at the end of the root node RAPID LEARNING leads to a performance improvement of 9.1 %. On all instances where at least 80 % of the variable are dual degenerate at the root node, we could observe a reduction of solving time by 28.8 %. Note that this was one of the two thresholds for the `degeneracy` criterion.

Table 5.3 shows a more detailed analysis of `degeneracy` compared to SCIP without RAPID LEARNING at all and RAPID LEARNING with configurations `onlyroot` and `nochecks`. We choose `degeneracy` as the best criterion, since it was one of two criteria that solved an additional instance, clearly showed the best search reduction, and was a close second to `leaves` with respect to running time. The results show that `degeneracy` is superior compared to all other settings with respect to solving time. Compared to `default`, `degeneracy` improves the solving time by 9.9 % and reduces the number of explored tree nodes by 20.1 % on the group of affected instances. Interestingly, `nochecks` is superior to `degeneracy` with respect to to the number of explored tree nodes. Notes, the columns $\mathbf{N}$ and $\mathbf{N_Q}$ are restricted to instances that could be solved to optimality by all settings (218 instances in group affected). This underlines the potential of the additional information gained by RAPID LEARNING, e.g., found solutions and conflict constraints. However, at the same time it shows the computational overhead when

Table 5.2: Computational results for every individual heuristic criterion on `MMM-IP`.

		S	T	N	T_Q	N_Q
Exp.1	`default`	304	50.92	2466	–	–
	`degeneracy`	306	48.02	2084	0.943	**0.845**
	`dualbound`	304	50.26	2369	0.987	0.961
	`leaves`	305	49.31	2347	0.968	0.952
	`obj`	**307**	51.23	2399	1.006	0.973
	`nsols`	304	47.94	2142	**0.941**	0.869
	`sblps`	304	50.38	2296	0.989	0.931
	`nochecks`	299	61.10	1925	1.200	**0.781**
	`onlyroot`	**307**	54.89	2404	1.078	0.975
Exp.2	`degeneracy + leaves`	306	47.81	2073	**0.939**	0.841
	`leaves + obj`	**307**	49.80	2284	0.978	0.926
	`all6criterion`	303	48.23	2030	0.947	**0.823**

Table 5.3: Aggregated computational results on `MMM-IP`. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

		`default`			`onlyroot`			`nochecks`			`degeneracy`		
	#	S	T	N	S	T_Q	N_Q	S	T_Q	N_Q	S	T_Q	N_Q
all	355	304	50.92	1016	307	*1.078*	1.008	299	*1.200*	**0.822**	306	**0.943**	**0.833**
affected	234	225	67.03	2434	228	*1.064*	1.011	220	*1.249*	**0.777**	227	**0.909**	**0.791**
≥ 10	181	172	180.91	5143	175	*1.091*	1.023	167	*1.274*	**0.748**	174	**0.884**	**0.755**
≥ 100	131	122	369.22	8931	125	*1.133*	1.030	117	*1.297*	**0.763**	124	**0.874**	**0.774**
≥ 1000	44	35	1258.32	57402	38	*1.263*	*1.154*	30	*1.453*	**0.809**	37	0.952	**0.726**

running Rapid Learning at local tree nodes without using the criteria developed in this thesis.

In a second experiment (Table 5.2, section Exp.2) we combined all individual criteria. Combining two or more criteria leads to more aggressive version of Rapid Learning since it runs if at least one of the chosen criteria is satisfied. The two (out of fifteen) best pairwise combinations as well as the (most aggressive) combination of all six criteria are shown in Table 5.2. For detailed results we refer to Table C.3 in Appendix C. Interestingly, no combined setting is superior to `degeneracy`. The combination of `degeneracy` and `leaves`, which were the two outstanding criteria in the individual test, performs almost the same as the `degeneracy` criterion alone.

For a final experiment we choose again `degeneracy` as the best criterion. Our final experiment evaluates the impact of the individual information gained from local Rapid Learning. To this end, we individually deactivated transferring variable bounds, conflict constraints, inference information, and primal feasible solutions (see Table 5.4; and Table C.4 in Appendix C). This experiment indicates that primal solutions are the most important information for the remainder of the MIP search. When ignoring solutions found during the CP search, the overall solving time increased by 10.4 %

Table 5.4: Performance impact of individual gained information on `MMM-IP`.

		S	T	N	T_Q	N_Q
Exp.3	`degeneracy`	306	48.02	2084	–	–
	`variablebounds`	305	48.69	2089	1.014	1.002
	`conflicts`	306	50.11	2225	1.044	1.067
	`infervals`	305	48.29	2179	1.006	1.046
	`primsols`	305	52.77	2349	1.099	1.127

(`primsols`). When ignoring conflict constraints, the original motivation of RAPID LEARNING, solving time increased by 2.4 % (`conflicts`). Both transferring variable bounds and inference information proved beneficial, with a 2.1 % (`variablebounds`) and 2.8 % (`infervals`) impact on performance, respectively. It is not surprising that finding primal solutions has the largest effect. Firstly, they are applied globally, in contrast to bound changes and conflicts. Secondly, highly dual degenerate problems are known to be cumbersome not only for MIP branching but also for primal heuristics (Berthold, 2014a), which means that solution-generating procedures that do not rely on solving LPs are particularly promising for such problems.

5.5 Conclusion

In this chapter, we extended the idea of RAPID LEARNING Berthold et al. (2010). Firstly, we generalized RAPID LEARNING to integer programs and described the details that were necessary for doing so: value-based inference branching, additional propagators and generalized conflict constraints, most of which were already available in SCIP. Secondly, we applied RAPID LEARNING repeatedly during the search. This generates a true hybrid CP/MIP approach, with two markedly different search strategies communicating information forth and back. To this end, we introduced six heuristic criteria to decide when to start local RAPID LEARNING. Those criteria are based on degeneracy information, branch-and-bound statistics, and the local structure of the problem. Our computational experiments showed a speed-up of up to 7 % when applying local RAPID LEARNING in SCIP. Calling local RAPID LEARNING depending on the local degree of dual degeneracy is the best strategy found in our experiments.

Interesting future work in this direction includes: extending the CP search to generate global conflicts at local nodes using an assumption interface, running the CP search in a parallel thread where whenever the MIP solver moves to a new node the CP search restarts from that node, and extending the method to handle problems that include continuous variables.

Chapter 6

Conflict-Driven Heuristics in Mixed Integer Programming

Two essential ingredients of modern mixed-integer programming (MIP) solvers are diving heuristics that simulate a partial depth-first search in a branch-and-bound search tree and conflict analysis of infeasible subproblems to learn valid constraints. So far, these techniques have mostly been studied independently: primal heuristics under the aspect of finding high-quality feasible solutions early during the solving process and conflict analysis for fathoming nodes of the search tree and improving the dual bound. In this chapter, we combine both concepts in two different ways. Firstly, we develop a diving heuristic that targets the generation of valid conflict constraints from the Farkas dual. We show that in the primal this is equivalent to the optimistic strategy of diving towards the best bound with respect to the objective function. Secondly, we use information derived from conflict analysis to enhance the search of a diving heuristic akin to classical coefficient diving.

6.1 Introduction

The most commonly used method to solve *mixed-integer programs* (MIPs) is the *linear programming*-based (LP-based) branch-and-bound algorithm (Dakin, 1965; Land and Doig, 1960). In modern MIP solvers, this procedure is accelerated by various extensions (see e.g., Bixby et al., 2000; Laundy et al., 2009). Two examples of those extensions are primal heuristics (see e.g., Fischetti and Lodi, 2010; Lodi, 2013; Berthold, 2014a) and conflict analysis as described this thesis (see, e.g., Section 2.4.2 and Chapter 3). A primal heuristic is an incomplete method without any guarantee of success, which is used to find feasible and improving solutions. Computational studies indicate that within a MIP solver, disabling all primal heuristics would lead to a deterioration of

solving time by approximately 11% – 32% (Berthold, 2014a) and 5% – 15% (Achterberg and Wunderling, 2013). Conflict analysis denotes a collection of techniques to learn from infeasible subproblems encountered during the MIP solve. The outcome of conflict analysis is a set of so-called conflict constraints that are used in the remainder of the solving process, e.g., for propagation. As a consequence, the proof of global optimality can be accelerated, mostly by reducing the number of subproblems that need to be explored, according to the study of Achterberg and Wunderling (2013) by as much as 28% on affected instances.

In this chapter, we propose two complementary ways of combining both concepts. Firstly, we develop a primal diving heuristic that explicitly aims to generate conflict constraints. As we show by elementary calculations, this amounts to an optimistic fixing of variables to their best bound with respect to the objective function. Previous approaches that are targeted to gain additional conflict information starting from a feasible subproblem are based on, for example, an involved random sampling approach (Dickerson and Sandholm, 2013) or use a black-box solver to perform a hybrid constraint programming and MIP search as discussed in Chapter 5. In contrast to that, our approach constitutes a more direct method.

Secondly, we use the information obtained by conflict analysis in order to guide the LP relaxation towards feasibility. To this end, we apply the concept of variable locks to conflict constraints and show that this type of locks is richer on information and yield a more dynamic criterion compared to variable locks as known from the literature (Achterberg, 2007b). We use this to develop a new diving heuristic that harnesses variable locks implied by conflict constraints. Our experiments indicate that this heuristic outperforms the well-known COEFFICIENT DIVING heuristic (Berthold, 2008).

To show how a MIP solver can benefit from the techniques presented in this chapter as supplementary features, we carry out a detailed computational study for which both heuristics were implemented within the academic MIP solver SCIP 6.0 (Gleixner et al., 2018). The heuristics presented in this chapter are – to the best of our knowledge – the first LP-based heuristics for MIP which explicitly produce and exploit conflict constraints.

This chapter is organized as follows. In Section 6.2 we give a brief overview of all the background we need in the remainder of this chapter: LP-based branch-and-bound, diving heuristics, and conflict analysis. In Section 6.3 we discuss how a diving heuristic can be used to generate additional conflict information explicitly. Afterward, we present a modification and extension of the well-known COEFFICIENT DIVING heuristic by using conflict information in Section 6.4. Finally, an intense computational study of the individual impact of both presented approaches is presented in Section 6.5. In

Section 6.6 we conclude.

6.2 Background

We consider MIPs of the form (2.1) which read as

$$\min\{c^\mathsf{T} x \mid Ax \geq b,\ \ell \leq x \leq u,\ x_j \in \mathbb{Z}\, \forall j \in \mathcal{I}\},$$

with objective coefficient vector $c \in \mathbb{R}^n$, constraint coefficient matrix $A \in \mathbb{R}^{m \times n}$, constraint right-hand side $b \in \mathbb{R}^m$, and variable bounds $\ell, u \in \overline{\mathbb{R}}^n$, where $\overline{\mathbb{R}} := \mathbb{R} \cup \{\pm\infty\}$. Moreover, let $\mathcal{I} \subseteq \mathcal{N} := \{1, \ldots, n\}$ be the index set of integer variables.

LP-based Branch-and-bound. During the branch-and-bound procedure as described in Section 2.2, subproblems are regularly fathomed, either due to bounding or infeasibility. In the first case, subproblems whose lower bound exceeds the global upper bound are disregarded because they cannot contain an improving solution. Therefore, it is evident that branch-and-bound algorithms benefit directly from finding good solutions as early as possible. These solutions either originate directly from the LP relaxation when all variables fulfill the integrality conditions in the LP solution, or are constructed by so-called primal heuristics (Fischetti and Lodi, 2010; Lodi, 2013; Berthold, 2014a). In the second case, the infeasibility of a subproblem is either proven by contradicting variable bound changes or by an infeasible LP relaxation. If a node is fathomed due to infeasibility modern MIP solvers use conflict analysis as described in Section 2.4 and Chapter 3 to "learn" from those subproblems. Note that every subproblem fathomed due to bounding can be interpreted as an infeasible subproblem after adding a cutoff constraint on the objective function that restricts the feasible region to improving solutions.

Diving Heuristics. A special type of primal heuristics are so-called *diving heuristics* such as fractional-diving and pseudo-cost diving (Berthold, 2008). The principle idea of diving heuristics comes from the branch-and-bound procedure itself. Starting from a feasible but fractional LP solution, diving heuristics alternate between fixing some integer variables to a rounded value based on a fractional LP solution and reoptimizing the LP relaxation. This procedure can be viewed as a partial tree search along one path from the current subproblem to a leaf. Diving heuristics use a special branching rule that usually tends towards feasibility. By contrast, branching rules for complete tree search such as reliability branching (Achterberg et al., 2005) aim at a good subdivision of the problem. In modern MIP solvers, the basic and simple idea of diving heuristics (see Algorithm 2) is extended by constraint propagation (see Algorithm 2 Line 8) and conflict analysis (see Algorithm 2 Line 11 and 15).

Algorithm 2: GENERIC DIVING PROCEDURE

Input : LP solution x^{LP}, rounding function ϕ, score function ψ

Output: Solution candidate $\hat{x}$ or `NULL`

```
1  x̂ ← NULL, x̃ ← x^LP
2  D ← {j ∈ I | x̃_j ∉ Z}                                   // diving candidates
3  while x̂ == NULL and D ≠ ∅ do
4      forall i ∈ D do
           1. Determine rounding direction: d_j ← φ(j)
           2. Calculate variable score: s_j ← ψ(j)
5      Select candidate x_j with maximal score s_j and current local bounds ℓ_j and
         u_j
6      Update D ← D \ j
7      if d_j == up then ℓ_j ← ⌈x̃_j⌉ else u_j ← ⌊x̃_j⌋
8      (optional) Propagate this bound change
9      Update D if propagation fixed some j ∈ D
10     if Infeasibility detected then
11         Analyze infeasibility, add conflict constraints, perform 1-level backtrack
12         If D = ∅ goto 20 or 5 otherwise
13     (optional) Solve local LP relaxation
14     if Infeasibility detected then
15         Analyze infeasibility, add conflict constraints, perform 1-level backtrack
16         If D = ∅ goto 20 or 5 otherwise
17     Update x̃ and D if LP was solved
18     if x̃_j ∈ Z for all j ∈ I or D == ∅ then
19         x̂ ← x̃
20 return x̂
```

Conflict Analysis for Infeasible LP Relaxations. If the LP relaxation of a subproblem of (2.6) with local bounds ℓ', u' is proven to be infeasible there exists a dual ray $(y, s) \in \mathbb{R}^m_{\geq 0} \times \mathbb{R}^n$ by the Lemma of Farkas (Farkas, 1902) (see Theorem 1 and Corollary 7) such that

$$y^\mathsf{T} A + s = 0 \tag{6.1}$$

$$y^\mathsf{T} b + \sum_{\substack{j \in \mathcal{N} \\ s_j > 0}} s_j \ell'_j + \sum_{\substack{j \in \mathcal{N} \\ s_j < 0}} s_j u'_j > 0. \tag{6.2}$$

Therefore, the dual proof of form (2.11)

$$(y^\mathsf{T} A)x \geq y^\mathsf{T} b$$

with $y \in \mathbb{R}^m_{\geq 0}$ satisfying (6.1) and (6.2) is globally valid. In Chapter 3 we have already described how these constraints can be collected, managed, strengthened, and used for constraint propagation to deduce tighter variable bounds in modern MIP solvers.

6.3 Farkas Diving

Our first aim is the design of a diving procedure such that the dual solution of the LP relaxation moves towards a valid Farkas proof, i.e., constraints (6.1) and (6.2) are satisfied. Suppose $x^\star$ is an optimal but fractional solution of a local LP relaxation with respect to bounds ℓ' and u'. Let $(y^\star, r^\star)$, with $r^\star := r^{\ell'\star} - r^{u'\star}$, be an optimal solution of the dual LP

$$\max\{y^\mathsf{T} b + \sum_{j\in\mathcal{N}} r^\ell_j \ell'_j - \sum_{j\in\mathcal{N}} r^u_j u'_j \mid y^\mathsf{T} A + r^\ell - r^u = c, y \in \mathbb{R}^m_{\geq 0}, r^\ell, r^u \in \mathbb{R}^n_{\geq 0}\}.$$

We call $r_j := r^\ell_j - r^u_j$ is the *reduced cost* of x_j, for all $j \in \mathcal{N}$. The dual solution $(y^\star, r^\star)$ is not feasible for (6.1) and (6.2) with $(y, s) = (y^\star, r^\star)$, but note that $(y, s) = (y^\star, r^\star - c)$ fulfills (6.1).

In order to reduce the violation of (6.2), we need to increase the lower bound ℓ'_j of x_j if $r^\star_j - c_j > 0$ and decrease the upper bound u'_j if $r^\star_j - c_j < 0$. By complementary slackness, all integer variables with fractional LP solution value have reduced costs zero, i.e., $r^\star_j = 0$. Here, without loss of generality we assume $\ell'_j, u'_j \in \mathbb{Z}$ for all $j \in \mathcal{I}$. Hence, tightening the lower or upper bound of variable j reduces the violation of (6.2) by $|c_j| \cdot d_j$, where

$$d_j := \begin{cases} \lceil x^\star_j \rceil - \ell'_j & \text{if } c_j < 0, \\ u'_j - \lfloor x^\star_j \rfloor & \text{if } c_j > 0. \end{cases} \tag{6.3}$$

Therefore, the rounding direction of a variable j is implied by the sign of the objective coefficient c_j, i.e., upwards if $c_j < 0$, downwards if $c_j > 0$.

The previous part of this section took a strictly dual point of view. When switching the perspective to the primal side, the above rounding procedure can be interpreted as follows. On variables with negative objective coefficients we always tighten the lower bounds, i.e., the solution values of those variables are pushed towards the upper bound, and vice versa. Since (2.1) is a minimization problem, all variables are rounded into the best direction with respect to the objective function c. If $c_j = 0$ neither pushing to the lower nor upper bound has a direct impact on the objective function. In that case, a natural choice for breaking this tie is to consider the *fractionality* $f_j := x^\star_j - \lfloor x^\star_j \rfloor$ of the corresponding LP solution value. This leads to the following diving heuristic, defined by a rounding function ϕ_F and scoring function ψ_F. For every variable $j \in \mathcal{I}$,

let

$$\phi_F(j) := \begin{cases} \texttt{up} & \text{if } c_j < 0 \text{ or } c_j = 0 \wedge f_j \geq \frac{1}{2}, \\ \texttt{down} & \text{if } c_j > 0 \text{ or } c_j = 0 \wedge f_j < \frac{1}{2}. \end{cases} \tag{6.4}$$

While we use the fractionality only for tie-breaking, other diving heuristics, e.g., fractionality diving (Achterberg, 2007b), use this criterion solely to determining the rounding directions.

In addition to the rounding direction ϕ_F, an order needs to be defined in which the diving candidates are explored. As discussed before, the violation of the dual infeasibility constraint (6.2) can be reduced by $|c_j| \cdot d_j$ when tightening the lower or upper bound of variable j. From the primal point of view, the potential change in the objective function depends on how much a variable can be pushed until it reaches one of its bounds. This change can be approximated by $|c_j| \cdot f_j^{rel}$, where

$$f_j^{rel} := \begin{cases} 1 - f_j & \text{if } \phi_{F(j)} = \texttt{up}, \\ f_j & \text{if } \phi_F(j) = \texttt{down}, \end{cases} \tag{6.5}$$

is the *relative fractionality* of $x_j^\star$, for all $j \in \mathcal{I}$. This measure is used by, e.g., pseudo cost diving (Achterberg, 2007b), to define an ordering in which the variables are explored during diving.

Combining both criteria, let the score of $j \in \mathcal{I}$ be given by

$$\psi_F(j) := |c_j| \cdot d_j \cdot f_j^{rel}. \tag{6.6}$$

A higher score is preferred.

In the following, we refer to this diving heuristic as FARKAS DIVING. Its rounding procedure pushes all variable towards the so-called *pseudo solution* (Achterberg, 2007b). In the pseudo solution, each variable takes the best bound with respect to its objective coefficient as solution value. This relaxation solution is overly optimistic and most of the time not feasible for the constraints $Ax \geq b$. However, if this strategy leads to a feasible solution, it may be expected to be very good.

6.4 Conflict Diving

We continue by exploring the complementary question of how conflict constraints can be used to guide the search of a diving heuristic. First, consider the following well-known concept.

Definition 23 (Variable Locks (Achterberg, 2007b))**.** *For a mixed integer program of form* (2.1)*, the number of* down-locks *and* up-locks *of variable* $j \in \mathcal{N}$ *is defined as*

the number of positive coefficients per column $\zeta_j^+ := |\{i \mid A_{ij} > 0\}|$ *and the number of negative coefficients per column* $\zeta_j^- := |\{i \mid A_{ij} < 0\}|$*, respectively.*

Starting at an LP solution $x^\star$ satisfying $Ax \geq b$, a variable $j \in \mathcal{I}$ with zero down-locks ζ_j^+ (with zero up-locks ζ_j^-) can always be set to its lower bound (upper bound) without increasing the violation of any constraint. On the other hand, if a variable has down-locks (up-locks), rounding the variable downwards (upwards) might increase the violation of at least one constraint. If a constraint down-locks variable j and is tight with respect to the LP solution candidate $x^\star$, rounding $x_j^\star$ downwards will violate the constraint. Hence, the variable locks measure the "risk" that rounding a variable leads to additional constraint violations.

Usually, only variable locks that are implied by model constraints (short: variable locks) are used during a MIP solve, e.g., during presolving, propagation, or primal heuristics. A well-known diving heuristic that solely relies on variable locks is Coefficient Diving (Berthold, 2008). Coefficient Diving as implemented in SCIP follows the diving scheme of Algorithm 2. For every variable the rounding direction is determined based on the variable locks only. For a variable j that is locked in both directions, i.e., $\zeta_j^- > 0$ and $\zeta_j^+ > 0$, Coefficient Diving prefers the direction with less variable locks, i.e., the "safe" direction. The order to process the variables during diving is given by the number of variable locks, too. Here, variables with many variable locks on the chosen direction are preferred.

Processing variables first that tend to lead to infeasibilities is often called a *fail fast strategy*. This strategy was introduced by Haralick and Elliott (1980) in the context of artificial intelligence and constraint programming. Later, Berthold (2014a) verified that taking the most critical decisions first is a good strategy for MIP.

Variable locks are a very static criterion and include also model constraints that either do not propagate frequently or are not tight at the current LP relaxation. For this reason, we propose to consider also variable locks implied only by conflict constraints (short: *conflict locks*), which can be defined analogous to Definition 23. The following lemma shows that conflict locks can have the effect of measuring the "risk" more accurately.

Lemma 24. *Let* $(y^\mathsf{T}A)x \geq y^\mathsf{T}b$ *be a dual proof derived from an infeasible LP and* (y, r) *a dual ray proving the infeasibility of this local subproblem. If the conflict contributes to the conflict up-locks (conflict down-locks) of* j*, then, there exists at least one model constraint that contributes to the variable up-locks (variable down-locks) of* j*.*

Proof. The coefficient of x_j in the conflict constraint $(y^\mathsf{T}A)x \geq y^\mathsf{T}b$ is $\bar{a}_j := \sum_{k=1}^m a_{kj} \cdot y_k$. If $\bar{a}_j < 0$, i.e., the conflict up-locks x_j then there must exist at least one constraint k with $a_{kj} < 0$ because $y \geq 0$. Hence, constraint k contributes to the variable up-locks of x_j. The analogous argument holds for $\bar{a}_j > 0$. □

This motivates the use of conflict locks: they measure the "risk" of violating both model and conflict constraints but focus on constraints that have been actively involved in pruning branch-and-bound nodes.

A similar concept which is used in SAT is VSIDS (variable state independent decaying sum) (Moskewicz et al., 2001). The VSIDS score takes the contribution of every variable (and its negated complement) into account. For every variable the number of clauses (in MIP speaking: conflict constraints) the variable is part of is counted. During continuing the search, the VSIDS are periodically scaled by a predefined constant. With this periodically scaling the weight of older clauses is reduced over the time and more recent observation are weighted higher. In contrast to VSIDS, conflict locks are not periodically scaled and only respect conflict constraints that are part at the current subproblem. This is especially interesting within a MIP solver that uses a pool-based approach to maintain the conflict constraints as we have discussed in Section 3.2. Therefore, conflict locks give rise to the current set of variables that are involved in conflict constraints, whereas VSIDS also incorporate past conflict information.

While classical COEFFICIENT DIVING solely relies on variable locks, we exploit Lemma 24 and use a combination of both variable and conflict locks. Given a weight $\kappa \in [0,1]$, the *up-weight* ρ_j^- and *down-weight* ρ_j^+ of a variable j is given as a convex combination of both lock types, i.e., $\rho_j^- := \kappa \cdot \xi_j^- + (1-\kappa) \cdot \zeta_j^-$ and $\rho_j^+ := \kappa \cdot \xi_j^+ + (1-\kappa) \cdot \zeta_j^+$, where ξ_j^- and ξ_j^+ denote the number of conflict up-locks and conflict down-locks, respectively.

Furthermore, we revert the rounding strategy of COEFFICIENT DIVING: we use a rounding function preferring the direction that is more likely to lead to infeasibilities whenever variable j has locks in at most one direction,

$$\phi_C(j) := \begin{cases} \texttt{up} & \text{if } \rho_j^- > \rho_j^+ \text{ or } \rho_j^- = \rho_j^+ \wedge f_j \geq \frac{1}{2}, \\ \texttt{down} & \text{if } \rho_j^+ > \rho_j^- \text{ or } \rho_j^- = \rho_j^+ \wedge f_j < \frac{1}{2}, \end{cases} \tag{6.7}$$

Here we may assume that all variables that have no locks at all, i.e., free variables, are already set to their best bound with respect to their objective coefficient. With this strategy we aim to guide the heuristic into parts of the search tree that are usually not explored by other heuristics. The order in which the diving candidates are explored is identical to the one used in COEFFICIENT DIVING,

$$\psi_C(j) := \begin{cases} \rho_j^- & \text{if } \phi_C(j) = \texttt{up}, \\ \rho_j^+ & \text{if } \phi_C(j) = \texttt{down}. \end{cases} \tag{6.8}$$

i.e., variables that have a large number of locks on the chosen rounding direction are preferred. With this scoring function we pursue a fail fast strategy in order to reduce the time spent by this heuristic. We use a fail fast strategy that is even more aggressive

than Coefficient Diving since we already choose the critical direction. As a result, the heuristic tries to process variables that tend to infeasibility at the beginning of the diving path before the degree of freedom is further reduced during the dive. In the following, we refer to this diving heuristic as Conflict Diving.

6.5 Computational Results

In order to investigate whether and how MIP solvers can benefit from the methods presented in this chapter, we carried out an extensive computational study regarding the individual impact of each heuristic. For each heuristic, we present computational results on its general performance impact, followed by additional experiments that provide more detailed insights regarding their particular properties.

In the first part of this section, we compare SCIP in its default configuration (`default`) to SCIP extended by Farkas Diving. We will refer to the latter setting by `farkdiving`. In the second part of this section, we compare the individual impact of Coefficient Diving and Conflict Diving, to which we will refer by `coefdiving` and `confdiving`, respectively. As a baseline we use SCIP without both lock-exploiting diving heuristics (`nolockdiving`).

All experiments were performed with the academic MIP solver SCIP (Gleixner et al., 2018) (git hash bf6a486, based on SCIP 6.0), using SoPlex 4.0 as LP solver. To evaluate the generated data the *interactive performance evaluation tool*[1] (IPET) was used. The experiments were run on a cluster of identical machines equipped with Intel Xeon E5-2690 CPUs with 2.6 GHz and 128 GB of RAM; a time limit of 7200 seconds was set. To account for the effect of performance variability (Lodi and Tramontani, 2013) all experiments were performed with four different global random seeds. As test set we used a union of Miplib 3 (Bixby et al., 1998), Miplib 2003 (Achterberg et al., 2006), Miplib 2010 (Koch et al., 2011), and the Cor@l (Linderoth and Ralphs, 2005) benchmark set. After removing all duplicates and problems that are known to be numerically unstable, the test set consists of 488 publicly available MIP problems, which we will refer to as MMMC. Every pair of MIP problem and seed is treated as an individual observation, effectively resulting in a test set of 1952 instances. We will use the term "instance" when referring to a problem-seed combination.

Aggregated results over all random seeds are shown in Table 6.1 and Table 6.3. Here, 5 and 11 instances, respectively, are excluded because at least one setting finished with numerical violations. Besides the results on MMMC, the tables state the impact on affected instances, i.e., instances for which the solving path differs among settings. Further, the subset of affected instances is grouped into a hierarchy of increasingly harder classes $\geq k$. Class $\geq k$ contains all instances for which all settings need at least

[1] https://github.com/GregorCH/ipet

Table 6.1: Aggregated computational results for Farkas diving on MMMC over four different random seeds. Relative changes by at least 5% are highlighted in bold.

		default					farkdiving				
	#	**S**	**T**	**N**	$\mathbf{F_{virt}}$	$\mathbf{I_{virt}}$	**S**	$\mathbf{T_Q}$	$\mathbf{N_Q}$	**F**	**I**
all	1947	1401	183	3366	2.653	0.806	1408	0.982	**0.947**	3.725	0.335
MIPLIB 2010	348	305	349	6225	3.454	0.828	307	0.966	**0.940**	4.862	0.379
affected	706	686	66	1204	4.238	0.564	693	**0.946**	**0.852**	5.924	0.585
≥ 10	529	509	186	2420	5.168	0.733	516	**0.918**	**0.808**	6.112	0.573
≥ 100	297	277	697	4444	6.997	0.980	284	**0.852**	**0.737**	6.862	0.690
≥ 1000	127	107	2599	8072	11.764	1.291	114	**0.837**	**0.715**	10.803	1.150
afterroot	273	270	34	1095	9.747	0.689	272	**0.879**	**0.783**	15.319	1.513

k seconds and can be solved by at least one setting within the time limit. As explained by Achterberg and Wunderling (2013), this excludes instances that are "easy" for all settings in an unbiased manner. Detailed tables with instance-wise computational results can be found in the electronic supplement.

6.5.1 Farkas Diving

We first present computational experiments regarding the general impact of FARKAS DIVING as proposed in Section 6.3. In this setup, FARKAS DIVING solved the LP relaxation at every diving node (cf. Line 13). Since this strategy is costly compared to other diving heuristics in SCIP, FARKAS DIVING was executed at local nodes of the search tree, if the heuristic could already find a feasible solution at the root node. Moreover, since FARKAS DIVING relies on the objective function, we executed the heuristic on instances with a nonzero objective function only. In the second part, we discuss additional computational experiments used to analyze the effect of the individual components of FARKAS DIVING.

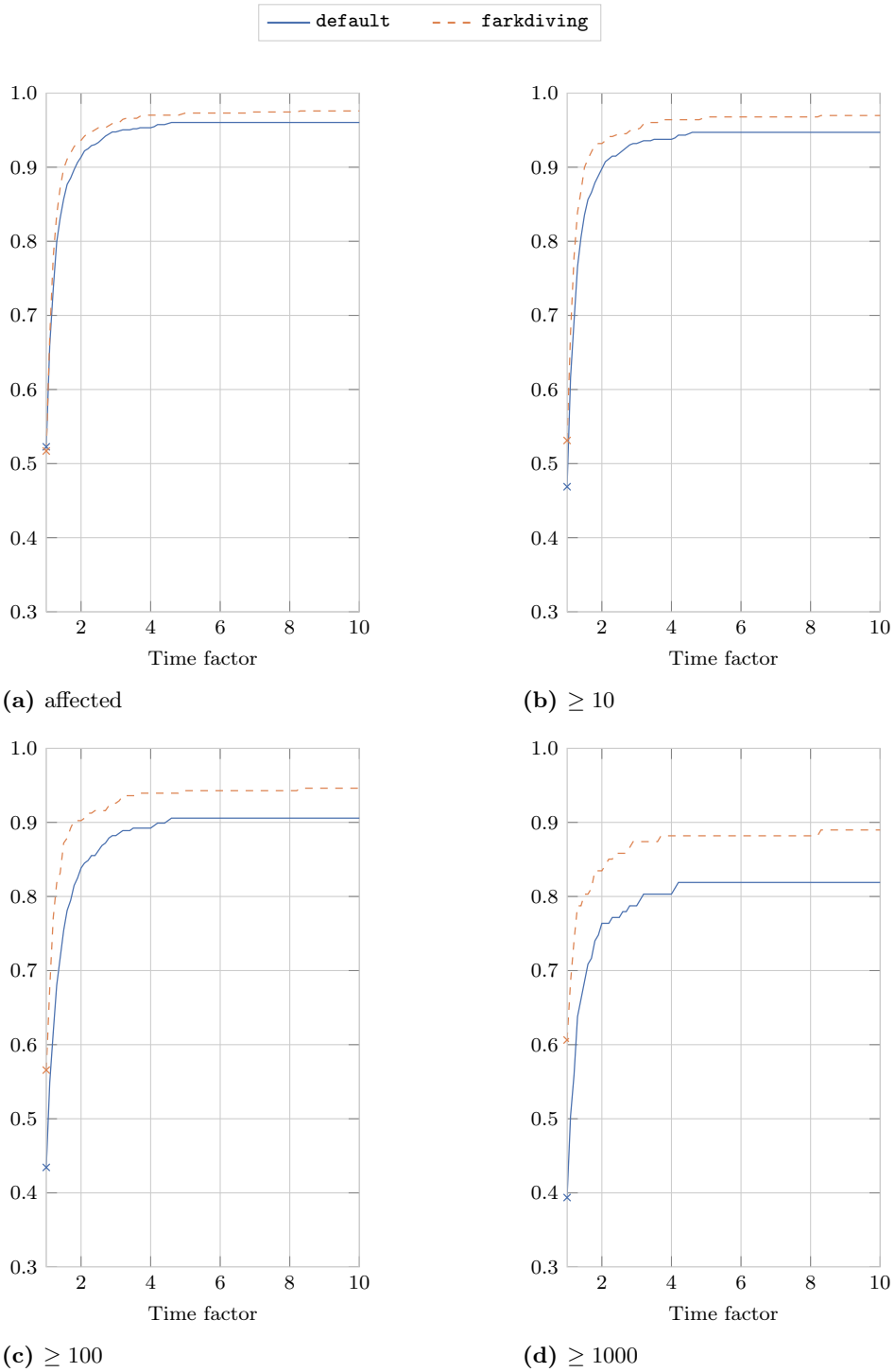
Overall Impact of Farkas Diving. Aggregated computational results comparing SCIP in its default configuration (`default`) and SCIP extended by FARKAS DIVING (`farkdiving`) on MMMC are shown in Table 6.1. Due to the restricted execution strategy described above, `farkdiving` affected only 706 out of 1947 instances. However, on these 706 instances `farkdiving` led to a speed-up of 5.4 % ($\mathbf{T_Q}$) and reduced the tree size by 14.8 % ($\mathbf{N_Q}$).

On the subset of harder instances ≥ 100 the overall performance could even be improved by 14.8 % and the size of the search tree could be reduced by more than 25 %. The observed performance improvement is spread over the complete group of affected instances. This becomes apparent also in the performance profiles (Dolan and Moré, 2002; Gould and Scott, 2016) displayed in Figure 6.1. For a time factor of 1.0 the respective amount of instances that could be solved best with the respective

setting is marked with a colored cross. In our experiments, we observed that on the set of affected instances, `default` performs best on 369 instances, whereas `farkdiving` was marginal worse and performs best on 365 affected instances. On this group of instances, both profiles cross exactly once at time factor 1.021. Afterward, `farkdiving` is always superior to `default`. This fact indicates that `farkdiving` is especially superior to `default` on harder instances and is confirmed by the performance profiles over instances where both settings need at least 10, 100 or 1000 settings. On these groups of affected instances, `farkdiving` is clearly superior to `default`. For a time factor of 1.0 `farkdiving` performs best the harder the instances are. On the group of affected instances for which both settings need at least 10 seconds, 248 can be solved best by `default`, whereas `farkdiving` performs best on 281 instances. These results indicate that Farkas Diving is expensive on easy instances compared to `default`, but superior on harder instances.

Success in Generating Conflicts. Farkas Diving is motivated by the idea of explicitly diving towards a valid Farkas proof. To analyze how successful Farkas Diving is in generating conflict constraints we considered all affected instances where Farkas Diving was allowed to run after the root node, i.e., instances where Farkas Diving was able to find a feasible solution at the root node. This subset contains 273 instances and is displayed in line "afterroot" of Table 6.1. On this subset of instances, Farkas Diving was able to find 7.3 % more conflict constraints than the "virtual best diving heuristic" in this regard. Here, the virtual best diving heuristic is determined by taking, for each instance run with `default` settings, the diving heuristic that generated the largest number of conflict constraints. Hence, Farkas Diving indeed succeeded in generating an above-average number of conflict constraints. Figure 6.2 provides a more detailed comparison of the number of generated conflict constraints for increasingly hard subgroups of afterroot.

The box plots (McGill et al., 1978) show for every setting and instance group the 1st and 3rd quartile (shaded box) as well as the median (dashed line). All observations below the 1st or above the 3rd quartile are marked with shaded diamonds. On all four groups of instances, Farkas Diving led to more conflict constraints in the median and 3rd quartile than the virtual best diving heuristic in this regard. On instances where both settings needed at least 1000 seconds, Farkas Diving produced on 50 % of the instances more conflict constraints than the virtual best diving heuristic of SCIP with `default` settings on 75 % did. These results indicate that the strategy of diving towards a valid Farkas proof as performed by Farkas Diving leads to additional conflict information and succeeds over the whole set where this strategy is pursued. Note that our analysis is conservative. The virtual best diving heuristic strictly overestimates every single diving heuristic, hence the number of additionally generated conflict constraints



(a) affected

(b) ≥ 10

(c) ≥ 100

(d) ≥ 1000

Figure 6.1: Performance profiles of `default` and `farkdiving` for four hierarchical groups of increasingly hard, affected instances.

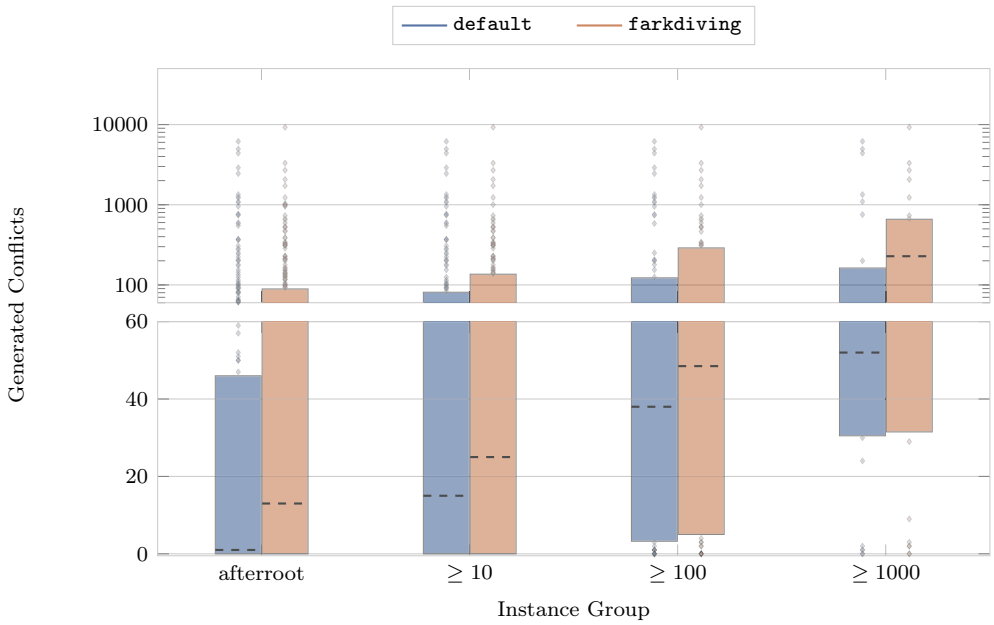


Figure 6.2: Box plot showing the number of generated conflicts by Farkas Diving when running with `farkdiving` and the virtual best diving heuristic when running with `default` on increasingly hard subgroups of afterroot.

would only increase when comparing to each diving heuristic individually.

Success in Generating Solution. Usually, the number of solutions found by diving heuristics is quite small (Khalil et al., 2017). From a primal viewpoint, Farkas Diving follows a rounding strategy which leads to overly optimistic solutions that are expected to be infeasible most of the time. However, if this strategy succeeds, the solutions can be expected to be very good. A more detailed look into the success rate of Farkas Diving with respect to finding primal solutions answers the question about the impact of these overly optimistic solutions on the overall MIP solver. In our experiments over several seeds, we could observe that on affected instances, Farkas Diving was able to find 39.7 % more feasible solutions (**F**) and 3.7 % more improving solutions (**I**) than the virtual best diving heuristic ($\mathbf{F}_{\mathbf{virt}}$ and $\mathbf{I}_{\mathbf{virt}}$) of SCIP with `default` settings. Here, the virtual best diving heuristic is determined as above, for each instance selecting the heuristic with the largest number of feasible and improving solutions, respectively. Again, both $\mathbf{F}_{\mathbf{virt}}$ and $\mathbf{I}_{\mathbf{virt}}$ overestimate every single diving heuristic in `default` setting. Note that this evaluation is conservative also in the sense that it includes instances for which Farkas Diving was not allowed to run at local nodes of the tree, i.e., instances where Farkas Diving did not find a solution at the root node, and, therefore, did not find a solution at all in these instances.

On the group of instances where Farkas Diving was allowed to run within the tree

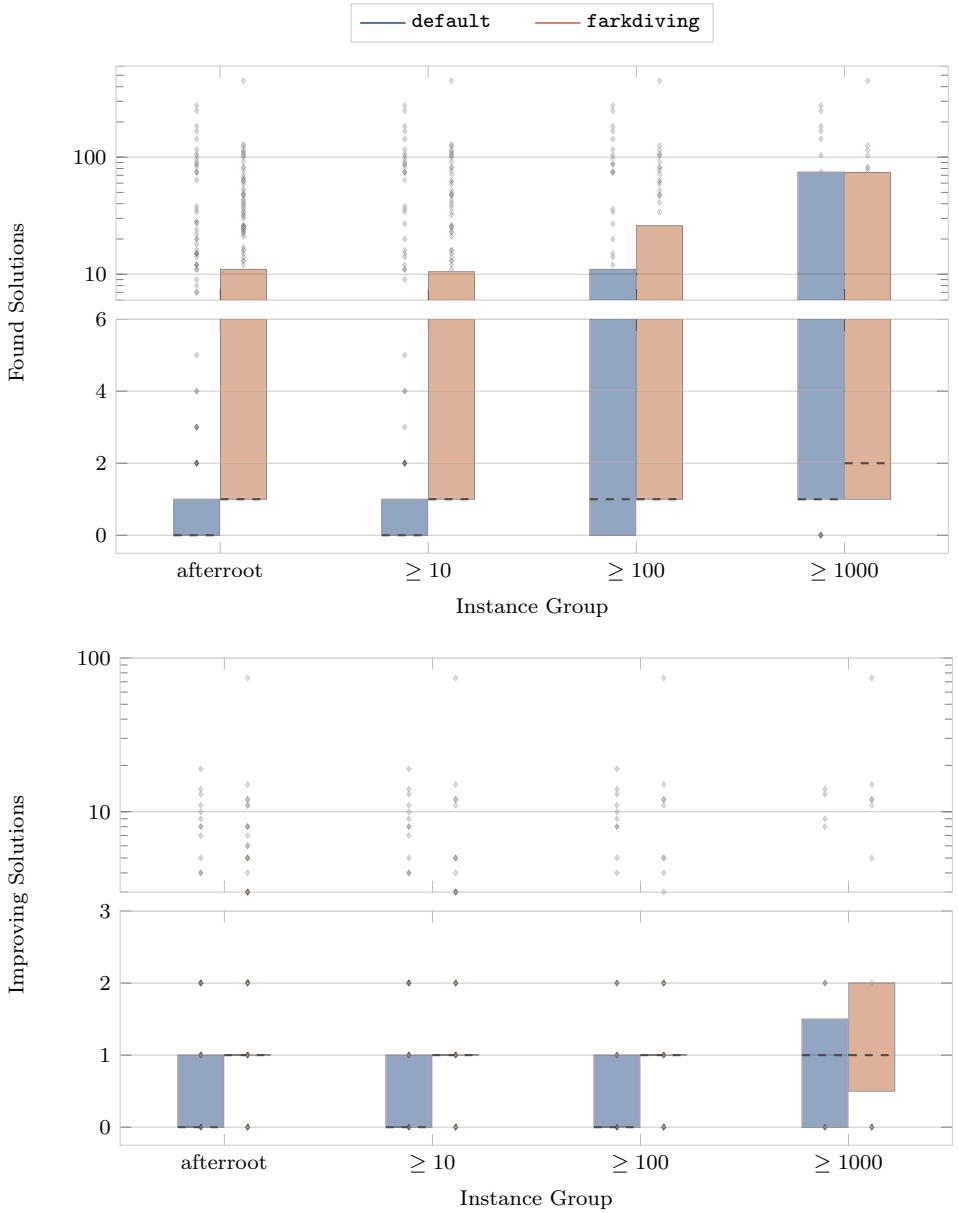


Figure 6.3: Box plots showing the number of feasible and improving solutions found by FARKAS DIVING when running with `farkdiving` and the virtual best diving heuristic when running with `default`.

(afterroot), the results are even more pronounced. Farkas Diving was able to find 57.2 % more feasible solutions and more than twice as many improving solutions than the virtual best diving heuristic in `default` setting. Figure 6.3 plots the relation of feasible and improving solutions found by Farkas Diving and the virtual best diving heuristic of `default` on increasingly hard groups of afterroot. The box plots show for every setting and instance group the 1st and 3rd quartile of all numbers of feasible and improving solutions, respectively, (shaded box) as well the median (dashed line). All observations below the 1st or above the 3rd quartile are marked with shaded diamonds. On all four groups of instances, Farkas Diving was able to find 10 or more feasible solutions on at least 25 % of the instances (observations above the 3rd quartile), whereas the 3rd quartile of the virtual best diving heuristic in this regard is always 1 for affected and ≥ 10. On hard instances for which both setting need at least 1000 seconds the 1st and 3rd quartiles of both `default` and `farkdiving` are identical. Note, the set afterroot only contains instances for which Farkas Diving was able to find at least one feasible solution at the root node. Thus, this set of instances is slightly biased; hence, it is not suitable to conclude that Farkas Diving finds more feasible solutions than the virtual best diving heuristic in general. However, the results on this set of instances indicate that the rule we used to decide whether Farkas Diving is allowed to run within the tree succeeds. On the complementary set consisting of 1562 instances that could be solved by at least one setting, i.e., those for which Farkas Diving was not able to find a solution root node, `farkdiving` succeeded with respect to finding at least one feasible solution within the tree on only 0.019 % of the instances. Considering the improving solutions found by the virtual best diving heuristic when running SCIP with `default` settings and Farkas Diving indicates that whenever Farkas Diving was allowed to run within the tree, i.e., it founds a feasible solution at the root node, Farkas Diving yields at least one improving solution on 75 % (all observations above the 1st quartile) of the instances of afterroot, ≥ 10, and ≥ 100. By contrast, the 1st and 3rd quartile of the virtual best diving heuristic are 0 and 1, respectively. Consequently, we can conclude that on instances that are cumbersome for the established diving heuristics of SCIP 6.0 with respect to finding solutions, Farkas Diving can easily find both feasible and improving solutions if it is allowed to run within the tree.

However, the pure amount of feasible and improving solutions alone is not meaningful enough to conclude whether the solutions found by Farkas Diving have a positive impact on the overall MIP solver. Therefore, we consider also the *primal integral* (Berthold, 2013), which measures the progress of the primal bound towards the optimal solution. Compared to `default`, `farkdiving` improved the primal integral by 12.3 %. This exhibits, maybe surprisingly so, that the optimistic strategy of Farkas Diving is also very successful on the primal side and, thus, a valuable extension to the portfolio of primal heuristics.

Table 6.2: `farkdiving` with and without adding feasible solutions and generated conflict constraints, respectively.

	#	S	T	N	T_Q	N_Q
`default`	273	270	33.82	1095	1.000	1.000
`farkdiving`	273	272	29.75	857	0.879	0.783
`farkdiving-noconfs`	273	266	31.79	976	0.940	0.891
`farkdiving-nosols`	273	269	32.73	1045	0.968	0.954

Impact of Primal Solutions and Generated Conflicts. The previous results indicate that FARKAS DIVING both produces an above-average number of solutions and conflict constraints if it is allowed to run within the tree, but do not finally answer which component is more relevant for performance. We tried to quantify this by testing two modified versions of FARKAS DIVING: one that disables conflict analysis (`farkdiving-noconfs`) and one that discards feasible solutions found by FARKAS DIVING (`farkdiving-nosols`). The aggregated results are reported in Table 6.2. For this experiment, we used the subset of 273 instances where FARKAS DIVING was allowed to be executed after the root node when running FARKAS DIVING, i.e., afterroot.

Both settings solve fewer instances than `default`. This result is not surprising since both `farkdiving-noconfs` and `farkdiving-nosols` spend computational time for running FARKAS DIVING. As we have already discussed, FARKAS DIVING is much more expensive than other diving heuristics in SCIP since it solves the LP at every node during diving. Consequently, by not performing conflict analysis or not adding feasible solutions during FARKAS DIVING one of the key ingredients is missing. Thus, on a few instances, FARKAS DIVING needs the impact of both found solutions and generated conflict constraints to compensate the computational overhead compared to `default`.

When disabling conflict analysis (`farkdiving-noconfs`) the performance improvement compared to `default` decreased from 12.1 % to 6 %. The number of nodes explored during the tree search also increased (compared to `farkdiving`) but is still 10.9 % smaller than SCIP with `default` settings. Disabling the addition of primal solutions found by FARKAS DIVING to the main search (`farkdiving-nosols`) reduced the performance improvement compared to `default` from 12.1 % to 3.2 %, which corresponds to a slowdown by 9.2 % compared to `farkdiving`. Interestingly, the tree increased by 17.9 % compared to `farkdiving`. However, `farkdiving-nosols` still led to 4.6 % smaller trees than SCIP with `default` settings.

In hindsight, it is not very surprising that disabling the addition of solutions has a larger impact than disabling conflict analysis during FARKAS DIVING. With the very optimistic rounding strategy, FARKAS DIVING was able to find 3.2 times as many

best solutions[2] as all remaining diving heuristics together. Overall, on afterroot, 5.7 % of all best solutions were found by Farkas Diving. The only heuristic that was even more effective on this set of instances is the large neighborhood search heuristic Rens (Berthold, 2014b), which contributed 7.9 % of all best solutions. Thus, Farkas Diving has a remarkable success rate, which leads to a not negligible impact on the primal side. As mentioned above, this is also reflected by the primal integral (Berthold, 2013), which improved by 12.3 % when running Farkas Diving during the tree search (afterroot).

These results make clear that both the primal and dual aspects of Farkas Diving contributes to the improved performance, but that the solutions found with the strategy of Farkas Diving seem to be the main driver of the heuristic. This may come as a surprise because our initial motivation for the design of Farkas Diving was the targeted generation of conflict constraints.

Impact of LP Frequency. By default, all diving heuristics in SCIP are configured to solve the LP dependent on the number of found bound deductions during constraint propagation over all variables. An LP solve is triggered whenever the number of bound changes since the last LP solve exceeds 0.15 times the number of variables. By contrast, Farkas Diving solves the LP at every diving node. One motivation for this high LP frequency is to "pull" the variable assignments back towards the feasible region in order to counteract the very optimistic rounding strategy of Farkas Diving, which tends to "push" the variable assignments out of the feasible region.

Within SCIP, every LP solution found during diving is automatically rounded to a solution satisfying all integrality requirements of the variables. If this solution also satisfies all constraints, i.e., is feasible for the entire MIP, the solution is added to the solution storage, whereby the diving heuristic that performs the current dive is credited for finding the feasible solution. Thus, Farkas Diving may have a slight advantage over all other diving heuristics since it solves the LP relaxation more frequently. This fact might be one reason why Farkas Diving was able to find more than 40 % more solutions than the virtual best ($\mathbf{F}_{\mathbf{virt}}$), see Table 6.1. Hence, in a final control experiment, we configured Farkas Diving identically to all remaining diving heuristics in order to measure the impact of the increased LP frequency. We will refer to this configuration by `farkdiving-lp`.

On the set of affected instances for which our criteria for running Farkas Diving within the tree is satisfied (afterroot), `farkdiving-lp` performed almost as "poorly" as `farkdiving-nosols` (see Table 6.2) with respect to solving time, nodes, and number of solved instances. Thus, when using `farkdiving-lp` the solving time could be improved

[2] A solution is called 'best' if it is an optimal solution or the best-known solution when reaching the time limit.

by only 3.5 % compared to `default`. Note, on the same set of instances `farkdiving` led to a speed-up of 12.1 %. Compared to `farkdiving`, the amount of feasible solutions found by `farkdiving-lp` was reduced by 90 %.

These results show that solving the LP relaxation frequently gives an important boost to the degree by *how much* FARKAS DIVING improves performance. However, also FARKAS DIVING with less LP solves, i.e., configured identically to all remaining diving heuristics, outperforms the `default` settings. Consequently, the fact *that* FARKAS DIVING works indeed seems to be a result of its specific choice of rounding function ϕ_F and scoring function ψ_F.

6.5.2 Conflict Diving

The new CONFLICT DIVING is closely related to the existing COEFFICIENT DIVING in the sense that they both exploit lock information and follow the same diving framework of Algorithm 2. Hence, we chose to include both in the computational analysis and compare their impact individually to SCIP without any of these lock-exploiting diving heuristics. In the following, we will refer to the latter setting by `nolockdiving`. We will refer to SCIP with CONFLICT DIVING and with COEFFICIENT DIVING activated by `confdiving` and `coefdiving`, respectively. We first present computational experiments to quantify the general performance impact, followed by further computational results to analyze the impact of individual components in more detail.

Overall Impact of Conflict Diving. In our computational setup, CONFLICT DIVING used the same parameter settings as COEFFICIENT DIVING, e.g., frequency of execution and LP solve frequency. The parameter to weight variable and conflict locks within CONFLICT DIVING was set to $\kappa = 0.75$, i.e., conflict locks dominate by a factor of 3. Aggregated computational results of all three configurations on MMMC are shown in Table 6.3.

While `coefdiving` only showed minimally improved performance compared to `nolockdiving`, the setting `confdiving` was clearly superior. Conflict diving increased the number of solved instances by 16 (**S**), led to an overall speed-up of 4.8 % ($\mathbf{T}_\mathbf{Q}$), and reduced the tree size by 5.5 % ($\mathbf{N}_\mathbf{Q}$) on affected instances. On the subset of affected instances, `confdiving` needed 4.6 % less solving time and up to 6.8 % fewer nodes compared to `coefdiving`. The node reduction on the affected instances may be explained by the increased number of generated conflict constraints (**C**).

Concerning the number of solutions, we observed that `confdiving` was only slightly more successful: `confdiving` found 11.1 % more feasible solutions and 4.7 % more improving solutions than `coefdiving`. The impact of these additional solutions is reflected by the primal integral, which decreased by 4.7 % compared to `coefdiving` and by 4.9 % compared to `nolockdiving`. However, both heuristics had a small success rate

Table 6.3: Aggregated computational results for coefficient and conflict diving on MMMC over four different random seeds. Relative changes by at least 5% are highlighted in bold.

		nolockdiving			coefdiving				confdiving			
	#	**S**	**T**	**N**	**S**	$\mathbf{T_Q}$	$\mathbf{N_Q}$	**C**	**S**	$\mathbf{T_Q}$	$\mathbf{N_Q}$	**C**
all	1941	1372	216	3108	1381	0.998	1.003	1386.4	1388	0.978	0.972	1364.4
Miplib 2010	347	297	425	5788	299	1.008	1.015	374.9	300	0.986	0.975	343.6
affected	861	822	186	4259	831	0.998	1.014	686.2	838	0.952	**0.945**	892.2
≥ 10	775	736	287	5356	745	0.998	1.018	760.9	752	**0.948**	**0.941**	990.0
≥ 100	542	503	707	7982	512	0.988	1.000	1045.2	519	**0.932**	**0.923**	1377.9
≥ 1000	246	207	2365	19538	216	0.984	0.981	2068.5	223	**0.874**	**0.882**	2820.5

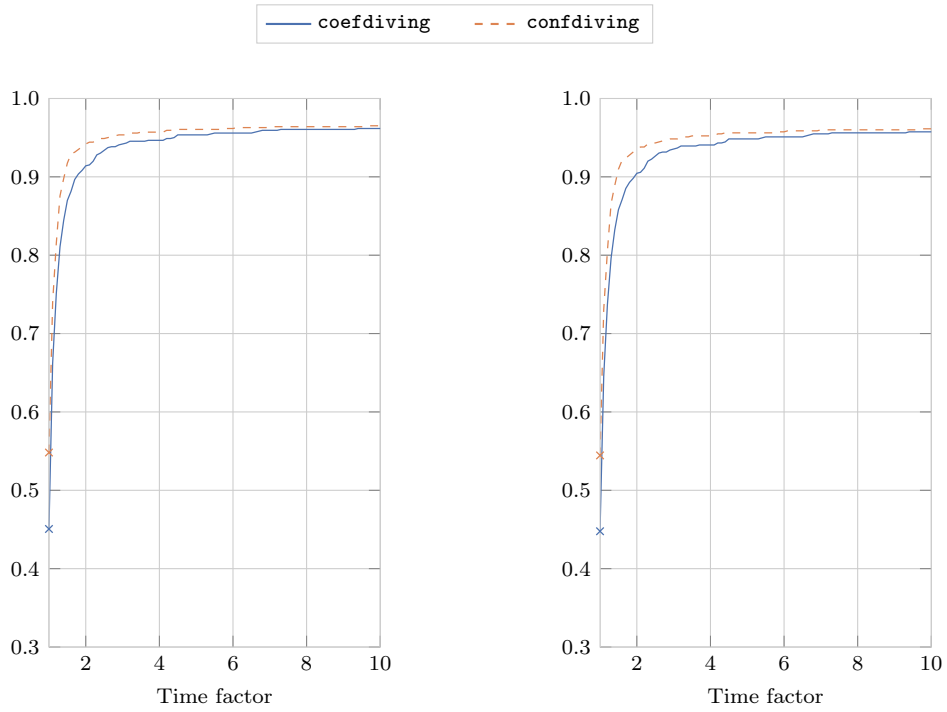
with respect to finding solutions: 0.037 (Conflict Diving) and 0.035 (Coefficient Diving) solutions per dive.

Finally, the performance profiles in Figure 6.4 show that the overall performance improvement was not caused by few instances but was spread over the complete group of affected instances: `confdiving` dominates `coefdiving` on all four groups of increasingly hard instances. For a time factor of 1.0 the respective percentage of instances that could be solved fastest with the respective setting is marked with a colored cross. On all four groups of instances, `confdiving` is clearly superior to `coefdiving` in the sense that the profiles do not cross. Between 52.0 % and 54.8 % of the instances in the respective group were solved fastest by `confdiving`, whereas only between 44.8 % and 46.5 % of the instances were solved fastest by `default`.

Length of Diving Paths. Both the rounding and scoring functions used by Conflict Diving aim for a fail fast strategy (Haralick and Elliott, 1980; Berthold, 2014a). In order to analyze whether Conflict Diving indeed achieves this design goal, we additionally measured the average length of diving paths for `coefdiving` and `confdiving`. On average, `confdiving` exhibits 30.2 % shorter diving paths than `coefdiving` on affected instances.

The distribution of the length of diving paths over the subsets of affected instances can be seen in Figure 6.5. The box plots show for every setting and instance group the 1st and 3rd quartile of all diving path lengths (shaded box) as well the median (dashed line). All observations below the 1st or above the 3rd quartile are marked with shaded diamonds. For all four instance groups, the 1st and 3rd quartile corresponding to Conflict Diving are smaller than for `coefdiving`. The same observation holds for the median in all cases. For example, on ≥ 100 the 3rd quartile (149) of Coefficient Diving is 69.3 % larger than the 3rd quartile (87) of Conflict Diving. On the same group of instances, the observed median path length of Conflict Diving is 23.6 % shorter than the one of Coefficient Diving.

As we already discussed, both Coefficient Diving and Conflict Diving showed



(a) affected

(b) ≥ 10

(c) ≥ 100

(d) ≥ 1000

Figure 6.4: Performance profiles of `coefdiving` and `confdiving` for four hierarchical groups of increasingly hard affected instances.

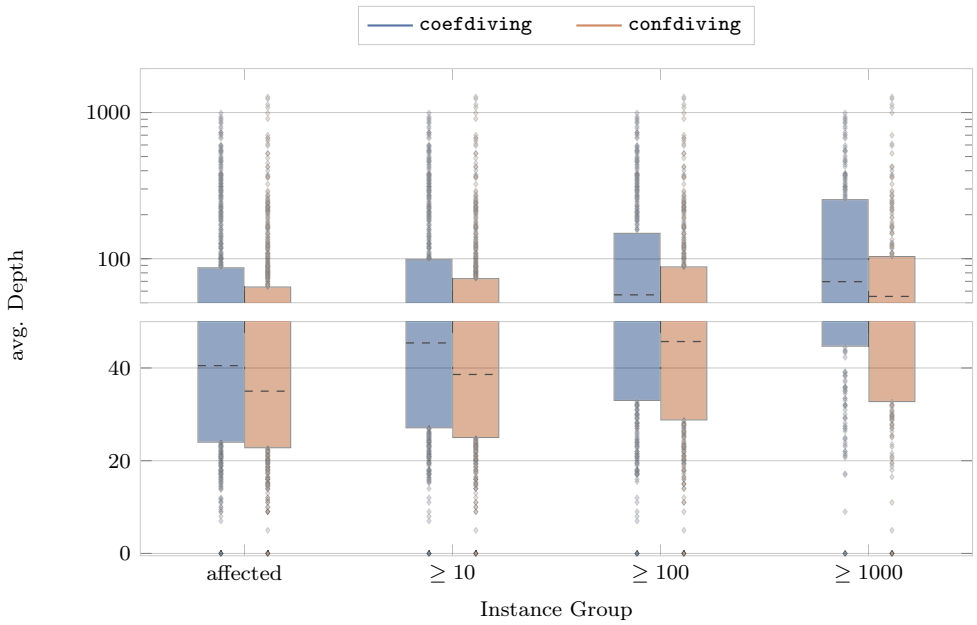


Figure 6.5: Box plots showing the average depth of diving paths generated Coefficient Diving with `coefdiving` and Conflict Diving with `confdiving` on the set of affected instances.

only a small number of found solutions per diving path, which is a good proxy for the number of successful paths, i.e., paths without backtracking due to infeasibility (cf. Line 11 and 15). Thus, these statistics confirm that Conflict Diving succeeds better in implementing a fail fast strategy and aborting the many "unsuccessful" dives not leading to a feasible solution early.

Moreover, this does not come at the expense of learning less conflict constraints. As can be seen in column **C** of Table 6.3, `confdiving` created 30.0 % more conflict constraints.

Impact of Conflict Locks. In order to investigate whether Conflict Diving outperforms Coefficient Diving because of the inclusion of conflict locks or merely because of the difference in the rounding and scoring function, we conducted two further control experiments with

- a modified rounding function within Conflict Diving and
- different weights κ.

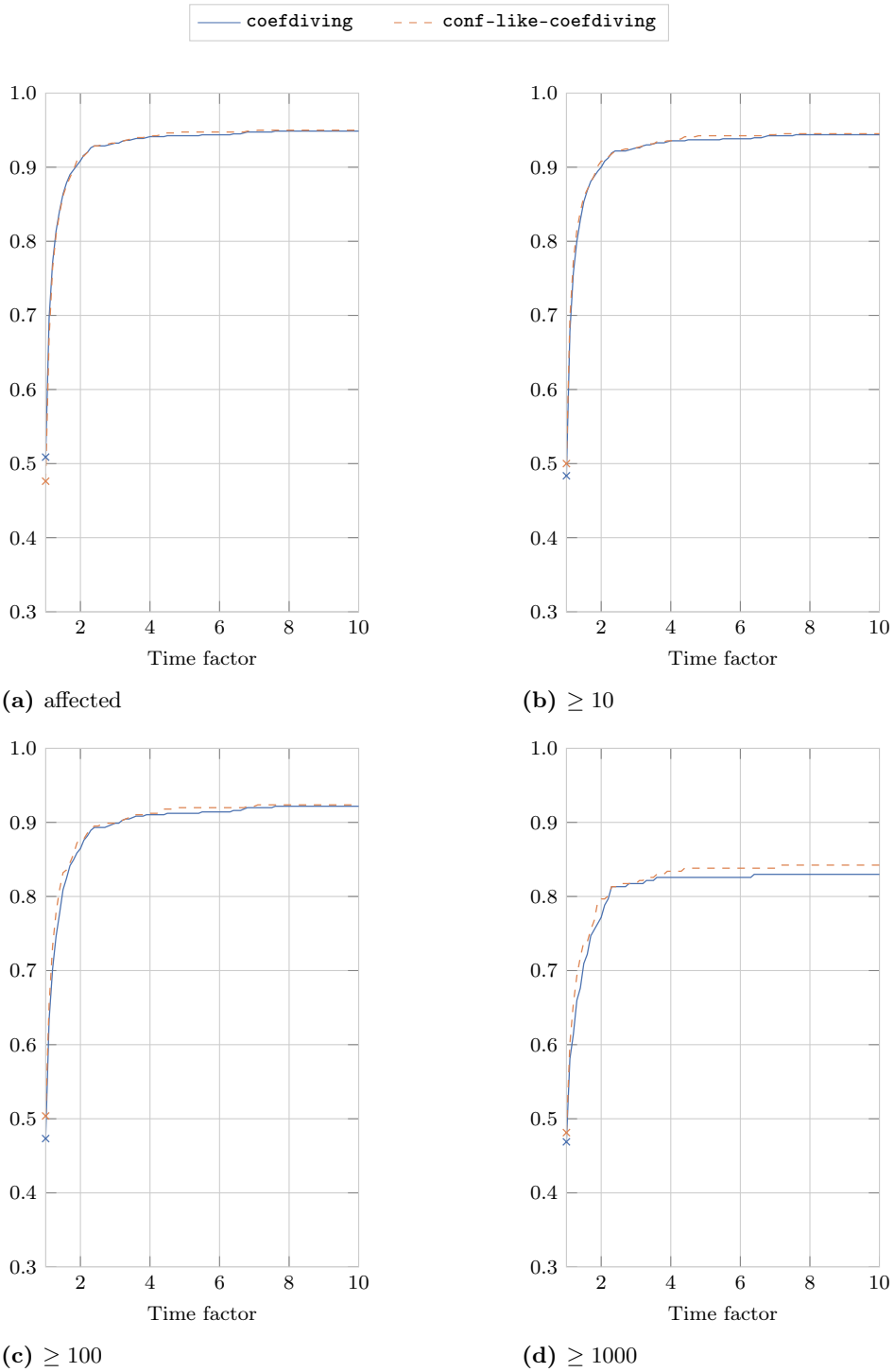
For the first control experiment we modified Conflict Diving to use the same rounding function as `coefdiving` and $\kappa = 0.5$ for the scoring function. The resulting

diving heuristic `conf-like-coefdiving` behaves the same as COEFFICIENT DIVING except for using a convex combination of variable and conflict locks in the variable selection score.

In our experiment `conf-like-coefdiving` was superior to `coefdiving` and led to a performance improvement of 2.3 % on the set of affected instances. At the same time, the tree size could be reduced by 3.6 % and four more instances could be solved. Similar to the version of CONFLICT DIVING evaluated at the beginning of this section, CONFLICT DIVING with `conf-like-coefdiving` settings generated more than twice as many conflict constraints and found 8 % more improving solutions than COEFFICIENT DIVING. The performance profiles in Figure 6.6 show that CONFLICT DIVING with the same rounding function like COEFFICIENT DIVING performs better the harder the instance, i.e., whenever many conflict constraints and therefore reliable conflict locks can be expected. It is not surprising that for a time factor of 1.0, `coefdiving` solves more instances best when easy instances are considered, too, since the number of conflict constraints can be expected to be small and, thus, the information gained by conflict locks might not be reliable enough. Even though the profiles are close to each other, they do not cross if both settings need at least 10, 100, or 1000 seconds. This result indicates that it is the inclusion of conflict locks in general that helps to guide diving better than pure variable locks.

For the second control experiment we varied the weights $\kappa \in \{0, 0.25, 0.5, 0.75, 1\}$ in `confdiving` in order to quantify the importance of conflict locks. The results indicate that the reduced length of diving paths is independent of the weighting of variable and conflict locks. For every choice of κ the average length of diving paths was reduced by 18 % to 34 %. Hence, the length of the diving paths seems to mainly depend on the rounding function ϕ_C, which always prefers rounding into the "risky" direction, i.e., the direction with more locks. We also confirmed that `confdiving` is superior to `coefdiving` on the affected instances for every evaluated κ.

Moreover, we observed that on instances with zero objective function a smaller conflict weight κ yields superior performance, while for instances with nonzero objective function a larger weight κ for conflict information seems to be the better choice. This observation may be related to how and when the decisions of CONFLICT DIVING align with SCIP's default branching rule and when they complement it. To make this clear, further background information is necessary. For branching variable selection, SCIP combines reliability pseudocost-branching (Achterberg et al., 2005), which estimates dual bound improvement, and hybrid branching (Achterberg and Berthold, 2009), which includes conflict information via VSIDS (Moskewicz et al., 2001). Both VSIDS and conflict locks approximate the set of variables that frequently appear in conflict constraints. On problems with nonzero objective function typically the first, objective-based score dominates SCIP's branching decisions, while on pure feasibility



(a) affected

(b) ≥ 10

(c) ≥ 100

(d) ≥ 1000

Figure 6.6: Performance profiles of `coefdiving` and the Conflict Diving modification `conf-like-coefdiving` for four hierarchical groups of increasingly hard affected instances.

Table 6.4: `confdiving` with and without adding feasible solutions and generated conflict constraints, respectively, on the set of affected instances.

	#	S	T	N	T_Q	N_Q
`nolockdiving`	861	822	185.62	4235	1.000	1.000
`coefdiving`	861	831	185.25	4290	0.998	1.013
`confdiving`	861	838	176.57	3999	0.951	0.944
`confdiving-noconfs`	861	825	181.99	4131	0.980	0.976
`confdiving-nosols`	861	838	177.64	4006	0.957	0.946

problems the latter, conflict-based score has more impact. This explains that on feasibility problems a larger κ might align the decisions of CONFLICT DIVING unfavorably with the overall tree search and create redundancy; on the majority of problems with nonzero objective, where conflict information is underweighted in the branching rule, a larger κ enables CONFLICT DIVING to contribute more complementary information to the search. This suggests a further refinement of CONFLICT DIVING by adapting the weight κ dynamically to the problem at hand.

Impact of Primal Solutions and Generated Conflicts. Finally, we analyzed the importance of found solutions and generated conflict constraints by comparing `confdiving` to two artificially modified versions of CONFLICT DIVING: one that does not apply conflict analysis (`confdiving-noconfs`) and one that discards feasible solutions found by CONFLICT DIVING (`confdiving-nosols`). Aggregated results on the set of affected instances are shown in Table 6.4.

Both variants `confdiving-noconfs` and `confdiving-nosols` are superior to `coefdiving` with respect to solving time and number of nodes. Whereas `confdiving-nosols` solved the same amount of instances as `confdiving`, disabling conflict analysis led to solving 13 instances less than `confdiving`. Hence, disabling the addition of feasible solutions found by CONFLICT DIVING only has a marginal impact compared to standard CONFLICT DIVING. By contrast, disabling conflict analysis during CONFLICT DIVING leads to a slowdown of 3 % compared to `confdiving`. Thus, the conflict constraints generated during CONFLICT DIVING seem to be the main driver of the heuristic. This also aligns with our observations regarding the *dual integral* (2.16). The dual integral measures the progress of the dual bound towards the optimal objective value. This measure increased by 3.1 % on average when disabling conflict analysis, which indicates that the increased number of conflict constraints helps to accelerate convergence of the proof of optimality.

6.6 Conclusion

In this chapter, we presented two new ways how conflict analysis and primal heuristics can be combined to improve the performance of a MIP solver. We presented a primal heuristic, called Farkas Diving, that simultaneously aims to construct valid Farkas proofs and feasible solutions. By design, Farkas Diving is more expensive than previous diving heuristics in SCIP. Therefore, the heuristic is called conservatively, whereby the decision to keep the heuristic enabled for the remainder of the search is based on its success during the root node. On the set of instances on which Farkas Diving was executed after the root node, it proved to be very successful in generating improving solutions and conflict constraints. Regarding both metrics, Farkas Diving outperforms the virtual best of all other diving heuristics on this set of instances. Moreover, the overall solving time could be improved by 5.4 % and the tree size could be reduced by 14.8 % on the set of affected instances.

Furthermore, we applied the concept of variable locks to conflict constraints and used this additional information to guide the search of a second diving heuristic, called Conflict Diving. In addition, Conflict Diving pursues an aggressive fail fast strategy to prevent fruitless consumption of running time. This new diving heuristic is an extension and modification of the well-known Coefficient Diving heuristic. Our computational results indicate that this mix of variable and conflict locks in combination with an aggressive fail fast strategy outperforms Coefficient Diving on our complete test set. Conflict diving reduces the overall solving time and tree size on affected instances by 4.8 % and 5.5 %, respectively.

The two ways of combining primal heuristics and conflict analysis presented in this chapter have highlighted that primal and dual solving techniques within a general-purpose MIP solver are not independent and that they can not only interact randomly and create performance variability, but be combined beneficially in a targeted manner.

Chapter 7

Conflict Analysis for MINLP

The generalization of MIP techniques to deal with nonlinear, potentially nonconvex, constraints has been a fruitful direction of research for computational MINLP in the last decade. In this chapter, we follow that path in order to extend another essential subroutine of modern MIP solvers towards the case of nonlinear optimization: the analysis of infeasible subproblems for learning additional valid constraints. To this end, we derive two different strategies, geared towards two different solution approaches. These are using *local* dual proofs of infeasibility for *LP-based* branch-and-bound and the creation of *nonlinear* dual proofs for *NLP-based* branch-and-bound, respectively. We discuss implementation details of both approaches and present an extensive computational study, showing that both techniques can significantly enhance performance when solving MINLPs to global optimality.

7.1 Introduction

Mixed integer nonlinear programs (MINLPs) are arguably among the hardest optimization problems; at the same time, they feature a multitude of applications in Chemical Engineering (e.g., Biegler et al., 1997; Floudas, 2000; Kallrath, 2005; Witzig et al., 2018), Computational Biology (e.g., Phillips and Rosen, 1994; Liberti et al., 2008, 2009), Portfolio Optimization (e.g., Cornuéjols and Tütüncü, 2006) and many others.

Many modern solvers for MINLP are based on linear relaxations and the spatial branching method. Being based on a branch-and-cut algorithm, they work similarly to solvers for mixed integer programs (MIPs). The basic algorithm is enhanced by various presolving techniques, domain propagation algorithms, and primal heuristics. The analysis of infeasible subproblems, however, has not yet been studied for MINLP solving, despite it being an important component of modern MIP solvers. The two main approaches to analyze infeasibility of subproblems in MIP solving are *conflict graph*

analysis, see Section 2.4.1, and *dual proof analysis*, see Section 2.4.2 and Chapter 3. Both together are subsumed under the term *conflict analysis.*

In this chapter, we consider MINLPs of the form

$$\min_{x \in X} \{ f(x) \mid g_k(x) \leq 0 \; \forall k \in \mathcal{K}, \; h_e(x) = 0 \; \forall e \in \mathcal{E}, \; x_i \in \mathbb{Z} \; \forall i \in \mathcal{I} \}, \tag{7.1}$$

with convex objective function $f \colon X \mapsto \mathbb{R}$, nonlinear constraint functions $g_k \colon X \mapsto \mathbb{R}$, $k \in \mathcal{K} := \{1, \ldots, p\}$, continuously differentiable, possibly nonconvex, and affine functions $h_e \colon X \mapsto \mathbb{R}$, $e \in \mathcal{E} := \{1, \ldots, q\}$. Moreover, let $X \subseteq \mathbb{R}^n$ be a non-empty convex set, let $\mathcal{N} = \{1, \ldots, n\}$ be the variable index set and $\mathcal{I} \subseteq \mathcal{N}$ the set of integer variables. MINLP (7.1) is called *convex* when all g_k are convex. Otherwise, it is called *nonconvex*. If f is a linear function and all functions g_k, h_e are affine, we call (7.1) a *mixed integer program* (MIP).

For a general MINLP (7.1), we obtain its *nonlinear programming* (NLP) relaxation by omitting the integrality requirements. The MIP relaxation of an MINLP with a linear objective[1] is given by omitting all "truly" nonlinear constraints g_k, h_e and keeping only those that are representable as a linear constraint matrix, eventually enhanced by linear underestimators of some of the nonlinear constraints. When we omit both, the truly nonlinear constraints and the integrality requirements, we get a *linear programming* (LP) relaxation.

All three relaxations provide a lower bound on the optimal solution value of an MINLP of form (7.1). In theory, linear and convex smooth nonlinear programs are solvable in polynomial time (Khachiyan, 1979; Vavasis, 1995). Also in practice, both classes can be solved very efficiently (Bixby, 2002; Nocedal and Wright, 2006). In contrast, nonconvexities imposed by nonconvex functions or integer variables directly lead to problems that are computationally challenging in practice and $\mathcal{NP}$-hard in theory.

In this chapter, we focus on solving MINLPs either by LP-based or by NLP-based branch-and-bound. During a branch-and-bound search, roughly half of the considered subproblems are either found to be infeasible or subpoptimal, i.e., to exceed the bound given by the best solution found so far (which can be seen as a special case of infeasibility). In contrast to today's MIP solvers which feature various techniques to "learn" from infeasible and bound-exceeding subproblems as discussed in the beginning of this thesis, e.g., see Chapter 3, comparable MINLP techniques have been described only for a few special cases.

To close this gap, we introduce two variants of conflict analysis for general MINLP. The first is a straightforward generalization of MIP concepts to LP-based branch-and-bound for MINLP. Our additional contribution is the use of locally valid certificates of

[1] Linearity of the objective can be assumed without loss of generality since a nonlinear objective can be reformulated as a constraint which is bounded by an additional variable that in turn is minimized.

infeasibility to deal with locally valid linear approximations of nonconvex constraints. The second technique is a generalization of the theory of Farkas proofs to work with nonlinear relaxations in an NLP-based branch-and-bound. We show how we can use the dual multipliers of an infeasible convex NLP to generate a valid nonlinear constraint, which can be used for variable domain propagation in the remainder of the search. Moreover, we discuss various implementation details and present a thorough computational study of both techniques.

7.2 Background & Related Work

In the following, we will briefly discuss different algorithms and their implementations for solving MINLPs, provide the reader with the technical background of conflict analysis in MIP, and review related work on infeasibility in MINLP solving.

7.2.1 Solving MINLPs

Solution methods for convex MINLPs include the extended supporting hyperplane algorithm (Kronqvist et al., 2016) which is based on the extended cutting plane algorithm (ECP) (Westerlund and Pettersson, 1995), outer approximation (OA) (Duran and Grossmann, 1986; Fletcher and Leyffer, 1994), NLP-based branch-and-bound (Gupta and Ravindran, 1985), and LP/NLP-based branch-and-bound (Quesada and Grossmann, 1992). The most commonly used method to solve nonconvex MINLPs is a combination of either OA or ECP (Kocis and Grossmann, 1988; Viswanathan and Grossmann, 1990; Tawarmalani and Sahinidis, 2005; Lundell and Kronqvist, 2019) and spatial branch-and-bound (Land and Doig, 1960; Liberti and Pantelides, 2003; Horst and Tuy, 2013). During the tree search, many general purpose MINLP solvers use LP or MIP relaxations (or both) to derive dual bounds. Couenne[2] (Belotti et al., 2009) and SCIP[3] (Vigerske and Gleixner, 2018) only solve LP relaxations, whereas ANTIGONE[4] (Misener and Floudas, 2014), BARON[5] (Kılınç Karzan et al., 2009) and BONMIN[6] (Bonami et al., 2008a) use LP and MIP relaxations simultaneously. However, only few MINLP solvers have the ability to exclusively solve NLP relaxations during the search, e.g., BONMIN, Minotaur, and FICO Xpress[7] (Belotti et al., 2016; Mahajan et al., 2017). Notably, BONMIN by default chooses a hybrid strategy between LP-based and NLP-based branch-and-bound (Bonami et al., 2008a), demonstrating that ideally, new solving techniques are developed in a way that they can be

[2] https://github.com/coin-or/Couenne
[3] https://www.scipopt.org
[4] http://ares.tamu.edu/ANTIGONE/
[5] https://minlp.com/baron
[6] https://github.com/coin-or/Bonmin
[7] https://www.fico.com/en/products/fico-xpress-solver

incorporated into either paradigm. We refer to (Kronqvist et al., 2018) for a more detailed overview of solvers for convex and nonconvex MINLPs.

In the following, we will focus on MINLP solvers that use spatial branch-and-bound (with the linear relaxations, e.g., generated by an ECP). The spatial branch-and-bound method is a variant of LP-based branch-and-bound (Dakin, 1965; Land and Doig, 1960). The algorithm splits the search space sequentially into smaller and smaller subproblems, which are designed to be easier to solve. Every additional split strengthens the relaxation. For each subproblem, an LP relaxation is solved to compute a local lower bound. If this lower bound exceeds the incumbent solution, the subproblem can be pruned. Spatial branch-and-bound first branches on integer variables with a fractional solution value. If no such variable exist, it branches on variables appearing in nonconvex terms of nonlinear constraints that are violated by the current relaxation solution. This includes branching on continuous variables.

During a branch-and-bound procedure, some of the subproblems may be detected to be infeasible. This can either come from an infeasible relaxation or be detected by domain propagation deducing contradicting variable bounds. The goal of conflict analysis is to learn from these infeasibilities, in order to prune the search tree more efficiently going forward.

7.2.2 Conflict Analysis in MIP

To a certain extent, conflict analysis techniques for MIP can also be applied within MINLP solvers that rely on LP-based branch-and-bound. Hence, we will briefly recapitulate conflict analysis techniques as described in Chapter 3 of this thesis and discuss their limitations when carried-over one-to-one for solving MINLPs in the next subsection.

Here and in Section 7.3, we will assume the objective function of (7.1) to be linear. This happens without loss of generality, since a nonlinear objective can be reformulated as a constraint which is bounded from above by an additional variable that in turn is minimized.

Furthermore, we will use standard MIP notation whenever considering a MIP or an LP. Therefore, we will denote the linear objective as $f(x) = c^\mathsf{T} x$. Moreover, we treat the set of constraints $g_k(x) \leq 0, h_e(x) = 0$ as a constraint matrix of form $Ax \leq b$ by considering $-h_e(x) \leq 0$ and $h_e(x) \leq 0$ and moving the (potentially nonzero) constants of the affine functions to the right-hand side of the constraint matrix. Finally, the set X is represented by the intersection of variable bounds $\ell \leq x \leq u$ with $\ell, u \in \overline{\mathbb{R}}^n$, where $\overline{\mathbb{R}} := \mathbb{R} \cup \{\pm\infty\}$. Hence a MIP reads as

$$\min\{c^\mathsf{T} x \,|\, Ax \leq b,\ \ell \leq x \leq u,\ x_j \in \mathbb{Z}\, \forall j \in \mathcal{I}\}. \tag{7.2}$$

MIP, SAT, and CP solvers use a *conflict graph* to learn from infeasibilities discovered by domain propagation, see Section 2.4. Remember, the conflict graph is a directed acyclic graph, it represents the logic of how the set of branching decisions led to the detection of infeasibility. Each branching decision corresponds to a source node and the infeasibility is represented by an artificial sink vertex. Each cut that separates the branching vertices from the infeasibility vertex gives rise to a *conflict constraint*. A conflict constraint is a set of variable bounds, such that for all feasible solutions at least one of the variables has to take a value different from these bounds. If all involved variables are binary, this can be easily expressed as a linear constraints, however, even for other variable types, it can be efficiently propagated by a 2-watched literal scheme.

Similarly, for infeasible LP relaxations, *dual proof analysis* aims at identifying a set of variable bounds that are sufficient to make the subproblem infeasible within its local bounds ℓ' and u'. Such a set of variables leads to a *dual proof constraint*, see, e.g., Section 2.4.2. From LP duality theory and the Farkas lemma (see Section 2.3) we know that exactly one of the following two systems

$$Ax \leq b,\ \ell' \leq x \leq u' \tag{7.3}$$

$$y^\mathsf{T}A + r^u - r^\ell = 0,\ y^\mathsf{T}b + \sum_{j\in\mathcal{N}}(r^u_j u'_j - r^\ell_j \ell'_j) < 0,\ y, r^\ell, r^u \geq 0 \tag{7.4}$$

must be feasible. System (7.4) implies an infeasibility proof of (7.3) with respect to ℓ' and u'

$$\begin{aligned} & 0 > y^\mathsf{T}b + \sum_{j\in\mathcal{N}}(r^u_j u'_j - r^\ell_j \ell'_j) \\ \iff \quad & 0 > y^\mathsf{T}b - (y^\mathsf{T}A)\{\ell', u'\} \\ \iff & (y^\mathsf{T}A)\{\ell', u'\} > y^\mathsf{T}b, \end{aligned}$$

where $A_{\cdot j}$ denotes the j-th column of constraint matrix A and

$$(y^\mathsf{T}A)\{\ell', u'\} := \sum_{j\in\mathcal{N}:\ y^\mathsf{T}A_{\cdot j}>0} (y^\mathsf{T}A_{\cdot j})\ell'_j + \sum_{j\in\mathcal{N}:\ y^\mathsf{T}A_{\cdot j}<0} (y^\mathsf{T}A_{\cdot j})u'_j,$$

analogous to (2.10). As discussed in Section 2.4, $r^\ell, r^u \in \mathbb{R}^n_{\geq 0}$ represent the vector of dual variables on the finite bound constraints, i.e., for every variable j the reduced costs are given by $r_j := r^\ell_j - r^u_j$. Note, since every unfixed variable j can only be tight in at most one bound constraint, it follows by complementary slackness that at most one of r^ℓ_j, r^u_j will be nonzero.

Thus, $(y^\mathsf{T}A)\{\ell', u'\}$ is equivalent to the minimal activity with respect to the local

bounds ℓ' and u'. By construction, all feasible solutions have to satisfy

$$(y^\mathsf{T} A)x \leq y^\mathsf{T} b, \tag{7.5}$$

the *dual proof constraint*. This is a globally valid constraint because it is a conic combination of globally valid constraints. In that sense, dual proof constraints can be seen as a special case of Benders cuts (Benders, 2005). The (initial) dual proof constraint is further on used as a starting point for conflict graph analysis or dual proof analysis as described in Chapter 3. As defined in Section 2.4.2, *dual proof analysis* denotes the non-trivial modification of dual proof constraints, e.g., by lifting or elimination techniques. Both the constraints resulting from dual proof analysis and conflict constraints are typically used for propagation in the remainder of the MIP search, but they are not added to the LP relaxation.

Note that in MIP, conflict graph analysis might yield several conflicts per infeasibility. These might be of a disjunctive nature that is not necessarily linear, see Achterberg (2007a). In contrast, dual proof analysis yields exactly one linear constraint.

For further details on conflict analysis in MIP we refer to the beginning of this thesis, e.g., Section 2.4 and Chapter 3. In this chapter, we will focus on dual proof analysis for MINLP.

7.2.3 Conflict Analysis in MINLP

So far, there is only few literature on MINLP infeasibility. Further, those publications are typically limited to important special cases of MINLPs, e.g., conic certificates for convex MINLPs (Coey et al., 2020), a very powerful technique for solving *mixed integer second-order cone* (MISOCP) problems. Kellner et al. (2019) published a paper on finding irreducible infeasible subsystems of *mixed integer semidefinite programs* (MISDPs). Both publications consider global infeasibilities of the respective problems; they do not address analyzing infeasible subproblems to learn valid constraints or other information during the solution process.

For ECP- and OA-based solvers, existing MIP conflict analysis methods can be applied under certain conditions. Let us review the basic idea of constructing an LP relaxation of a MINLP.

Twice continuously differentiable functions on a bounded domain can be underestimated by linear functions. Thereby, the linear relaxation, which initially only consists of the linear constraints of the MINLP or even only of the bounding box, is refined step by step. Let $\tilde{x}$ be a solution of a relaxation with $g_k(\tilde{x}) > 0$, hence violating the constraint $g_k(x) \leq 0$. For convex functions g_k, *gradient cuts*

$$g_k(\tilde{x}) + \nabla g_k(\tilde{x})(x - \tilde{x}) \leq 0$$

are added. For nonconvex functions g_k, we can use convex underestimators to relax g_k. For example, for products of two variables, McCormick underestimators are used (McCormick, 1976). More general nonlinear functions are typically decomposed into functions of a single variable, for which explicit underestimators are known, and products of two variables. If such an underestimator itself is linear, it is added to the LP relaxation directly, otherwise a gradient cut for the underestimator is derived (e.g., Vigerske and Gleixner, 2018; Belotti et al., 2013). Note that gradient cuts derived from convex functions are globally valid. In contrast, for nonconvex functions, the local bounds typically are used for the construction of understimators. Consequently also the gradient cuts derived from these local understimators are not globally valid, but locally valid at the node for which they were created and its descendants.

For a subproblem s, let $\mathcal{G}^s := \{l_1^s, \dots, l_q^s\}$ be the index set of all linear approximations of all g_k with $k \in \mathcal{K}$ that have been added at the node corresponding to s or any of its ancestors. Hence, it is the current set of (local) *linear relaxation cuts*. Hence, all of them are valid for the current subproblem s. Let G^s be the matrix containing all of these linearizations and d^s be the corresponding right-hand sides. Thus, the LP relaxation solved for subproblem s reads as

$$\min\{c^\mathsf{T} x \mid Ax \leq b,\ G^s x \leq d^s,\ \ell' \leq x \leq u'\}. \tag{7.6}$$

We denote the set of linearizations added at the root node by $\mathcal{G}^0$. During the tree search, the set of linearizations grows along each path in the tree: It holds that $\mathcal{G}^0 \subseteq \mathcal{G}^{s_1} \subseteq \ldots \subseteq \mathcal{G}^{s_p} \subseteq \mathcal{G}^s$ for each path $(0, s_1, \dots, s_p, s)$ in the tree. Assume that (7.6) is infeasible. Like in the MIP case, each dual ray (y, w, r^ℓ, r^u) gives rise to a proof of (local) infeasibility of the linear relaxation. Here, y_i are the dual variables corresponding to $A_{i\cdot}$, w_l are the dual variables corresponding to $G^s_{l\cdot}$ for all $l \in \mathcal{G}^s$, and r^ℓ_j, r^u_j denote the reduced costs (the duals of the lower and upper bound constraints) of variable x_j. Note that the reduced costs of x_j are given by $c_j - y^\mathsf{T} A_{\cdot j} - w^\mathsf{T} G^s_{\cdot j}$.

Hence, a local infeasibility proof with respect to the local bounds ℓ' and u' is given by

$$y^\mathsf{T} b + w^\mathsf{T} d^s + \sum_{j \in \mathcal{N}} (r^u_j u'_j - r^\ell_j \ell'_j) < 0. \tag{7.7}$$

In contrast to (7.5) the constraint

$$y^\mathsf{T} Ax + w^\mathsf{T} G^s x \leq y^\mathsf{T} b + w^\mathsf{T} d^s \tag{7.8}$$

is not globally valid in general. This is due to how we construct linear underestimators of nonconvex constraints: they typically rely on local bounds of the current subproblem

or its ancestors. Conflict graph and dual proof analysis as introduced in Section 2.4.1 and 2.4.2 only consider globally valid reasons of infeasibility. To this end, the locally valid constraint (7.8) is relaxed to a globally valid constraint, considering only the dual multipliers for the original linear system $Ax \leq b$ and the globally valid linearization $G^0 x \leq d^0$:

$$y^\mathsf{T} Ax + \bar{w}^\mathsf{T} G^s x \leq y^\mathsf{T} b + \bar{w}^\mathsf{T} d^s, \tag{7.9}$$

where $\bar{w}_l := w_l$, if $l \in \mathcal{G}^0$, and $\bar{w}_l := 0$, otherwise. In general, this relaxed constraint might not prove infeasibility of subproblem s. If, however, (7.9) is a valid infeasibility proof, i.e., no locally valid linearization is needed to prove local infeasibility, we can use a relaxed infeasibility certificate

$$y^\mathsf{T} b + \bar{w}^\mathsf{T} d^s + \sum_{j \in \mathcal{N}} (\bar{r}^u_j u'_j - \bar{r}^\ell_j \ell'_j) < 0, \tag{7.10}$$

with $\bar{r} := c_j - y^\mathsf{T} A_{\cdot j} - \bar{w}^\mathsf{T} G^s_{\cdot j}$, to generate conflict constraints. In this case, (7.10) is an alternative infeasibility proof for subproblem s, no locally valid linearization is needed to prove local infeasibility, This implies that MIP conflict analysis techniques are readily available. As reported in Witzig et al. (2019), this situation could only be observed in 5 % of all infeasible subproblems. This observation corresponds to the result reported in Vigerske and Gleixner (2018) that applying conflict analysis techniques as used for solving MIPs has almost no impact when solving MINLPs. In the vast majority of cases, at least one locally valid linearization cut is needed to prove local infeasibility, and MIP conflict analysis cannot be readily applied. This brings us to the idea of local dual proofs.

7.3 Local Dual Proofs for LP-based Branch-and-Bound

For MIP solvers, both dual proof analysis and conflict graph analysis exclusively use infeasibility proofs which are globally valid. This is natural since MIP solvers typically do not use local cuts, or apply them only rarely. This is is an obvious difference to solvers for nonconvex MINLPs which inheritantly rely on applying local linearization cuts, as described in the previous section.

The crucial question is how to deal with linearization cuts that are only locally valid. Note that the same question might rise within a MIP solver using local cuts, e.g., FICO XPRESS. Analogous to MINLP, local cuts in MIP are based on variable bounds that are not globally valid.

We propose to lift local proofs of infeasibility from the current subproblem towards the root. This idea is motivated by two observations. First, an infeasibility proof at a

subproblem s of an LP-based branch-and-bound does not necessarily need to contain linearization cuts of nonconvex constraints created at the current node. Second, LP infeasibility proofs are typically not minimal. Consequently, it might be possible to set some of the proof's coefficients to zero and still have a valid proof of infeasibility, see also (Achterberg, 2007a). This brings us to the idea of performing a greedy search for a set $\hat{\mathcal{G}}$ with $\mathcal{G}^0 \subseteq \hat{\mathcal{G}} \subseteq \mathcal{G}^s$, such that $\hat{\mathcal{G}}$ gives rise to an infeasibility proof

$$y^\mathsf{T} b + \hat{w}^\mathsf{T} d^s + \sum_{j \in \mathcal{N}} (\hat{r}_j^u u'_j - \hat{r}_j^\ell \ell'_j) < 0 \tag{7.11}$$

of subproblem s. Here, ℓ' and u' are the local bounds at node s and $\hat{w}_l$ is defined as $\hat{w}_l := w_l$, if $l \in \hat{\mathcal{G}}$, and $\hat{w}_l := 0$, otherwise; consequently, $\hat{r}$ reads as $\hat{r}_j := c_j - y^\mathsf{T} A_{\cdot j} - \hat{w}^\mathsf{T} G^s_{\cdot j}$. The goal of the greedy search is to minimize $\hat{s} = 0, \ldots, s$, such that $\hat{\mathcal{G}} \subseteq \mathcal{G}^{\hat{s}}$.

It follows that the dual proof constraint derived from the infeasibility certificate (7.11) is a valid constraint for the part of the search tree which lies below the node corresponding to subproblem $\hat{s}$. Hence, it is possible to lift the proof constraint to an ancestor, here $\hat{s}$, of the subproblem s for which it has been created, given that all information that had been used to derive the proof constraint were already available at $\hat{s}$. In other words, node $\hat{s}$ is the ancestor of s closest to the root for which we can reduce the infeasibility proof such that is still a valid proof, but only uses globally valid linearizations plus local linearizations that have been created at $\hat{s}$ or one of its ancestors (but no local linearizations from the nodes between $\hat{s}$ and s or s itself).

In a similar fashion, we could apply conflict graph analysis to (7.11). Note that this would come with a nonnegligible computational overhead because we would need to track and maintain the order in which local linearizations were separated and track for all bound changes on which local linearizations they relied in order to be able to apply back propagation for conflict resolution. Hence, we refrain from applying conflict graph analysis in this setting in our implementation.

7.4 Nonlinear Dual Proofs for NLP-based Branch-and-Bound

NLP-based branch-and-bound is another common framework for solving MINLPs, in particular for convex MINLP where the nonlinear relaxations are tractable. In this section, we discuss theoretical considerations regarding how one can apply conflict analysis directly to convex relaxations of MINLPs. More precisely, we will describe a generalization of LP dual proof analysis, using the KKT conditions of convex NLPs. For ease of notation, we will assume in this section that the MINLP itself is convex, but all methodology can be generalized to convex relaxations of nonconvex MINLPs.

Given a convex MINLP

$$\min_{x \in X} \{ f(x) \mid g_k(x) \leq 0 \; \forall k \in \mathcal{K}, \; h_e(x) = 0 \; \forall e \in \mathcal{E}, \; x_j \in \mathbb{Z} \; \forall j \in \mathcal{I} \}, \tag{7.12}$$

where f, g_k are convex, continuously differentiable functions over $\mathbb{R}^n$ and h_e are affine functions. For every optimal solution $x^\star$ of (7.12) of the (convex) NLP relaxation of (7.12) there exists $\lambda \geq 0$ such that it holds that

$$\nabla f(x^\star) + \sum_{k \in \mathcal{K}} \lambda_k \nabla g_k(x^\star) + \sum_{e \in \mathcal{E}} \mu_e \nabla h_e(x^\star) = 0 \tag{7.13}$$

$$\lambda_k g_k(x^\star) = 0. \tag{7.14}$$

These are the *Karush-Kuhn-Tucker (KKT) conditions* (Kuhn and Tucker, 1951). The right-hand side of Equality (7.13) is the gradient of the *Lagrangian function*

$$\mathcal{L}(x, \lambda, \mu) := f(x) + \sum_{k \in \mathcal{K}} \lambda_k g_k(x) + \sum_{e \in \mathcal{E}} \mu_e h_e(x), \tag{7.15}$$

with $\lambda \geq 0$ and $\mu \in \mathbb{R}^{|\mathcal{E}|}$. The *Lagrangian dual function* $q \colon \mathbb{R}^{|\mathcal{K}|} \times \mathbb{R}^{|\mathcal{E}|} \mapsto \mathbb{R}$ is defined as

$$q(\lambda, \mu) := \inf_{x \in X} \mathcal{L}(x, \lambda, \mu). \tag{7.16}$$

Further, the dual problem of (7.12) is given by maximizing the Lagrangian dual function

$$\sup_{\lambda \geq 0, \mu} q(\lambda, \mu) := \sup_{\lambda \geq 0, \mu} \inf_{x \in X} \mathcal{L}(x, \lambda, \mu) \tag{7.17}$$

and yields the tightest lower bound on the optimal value of (7.12).

Following Boyd and Vandenberghe (2004, Section 5.8) we can formulate the following statement on weak alternatives.

Theorem 25. *Let $g_k : \mathbb{R}^n \mapsto \mathbb{R}$ with $k \in \mathcal{K}$ be convex, continuously differentiable functions over $\mathbb{R}^n$, $h_e : \mathbb{R}^n \mapsto \mathbb{R}$ with $e \in \mathcal{E}$ be affine functions, and let $X \subset \mathbb{R}^n$ be a convex set. At most one of the following statements will be satisfied.*

(a) There exists an $x^\star \in X$ such that $g_k(x^\star) \leq 0$ for all $k \in \mathcal{K}$ and $h_e(x^\star) = 0$ for all $e \in \mathcal{E}$.

(b) There exists $(\lambda^\star, \mu^\star) \in \mathbb{R}^{|\mathcal{K}|+|\mathcal{E}|}$ with $\lambda^\star \geq 0$ such that

$$q(\lambda^\star, \mu^\star) = \inf_{x \in X} \left\{ \sum_{k \in \mathcal{K}} \lambda_k^\star g_k(x) + \sum_{e \in \mathcal{E}} \mu_e^\star h_e(x) \right\} > 0. \tag{7.18}$$

Thus, in combination with the current local bounds $(\lambda^\star, \mu^\star)$ proves infeasibility of MINLP (7.12) and by construction

$$\sum_{k\in\mathcal{K}} \lambda_k^\star g_k(x) + \sum_{e\in\mathcal{E}} \mu_e^\star h_e(x) \leq 0 \tag{7.19}$$

is a valid inequality for (7.12).

Note, the above theorem only gives a statement on weak alternatives, thus, with the assumption we made so far it might be possible that the system

$$g_k(x) \leq 0 \ \forall k \in \mathcal{K} \quad \text{and} \quad h_e(x) = 0 \ \forall e \in \mathcal{E}$$

is infeasible but no (λ, μ) with $\lambda \geq 0$ exists such that $q(\lambda, \mu) > 0$ is satisfied. For the remainder of this chapter and in our implementation, strong alternatives are not necessary. To achieve strong alternatives for the convex case such as for the linear case, see Theorem 1 or Corollary 7, one would need to make two further assumptions. There has to exist an $x \in X$ such that

$$g_k(x) < 0 \ \forall k \in \mathcal{K} \quad \text{and} \quad h_e(x) = 0 \ \forall e \in \mathcal{E}$$

and the optimal value of the primal NLP is attained (Boyd and Vandenberghe, 2004). In other words, the NLP relaxation of (7.12) has to be strictly feasible.

Proposition 26. *Any solution $(\lambda^\star, \mu^\star)$ satisfying (7.18) is a ray in the dual.*

Proof. Let $\alpha > 0$ and $(\lambda^\star, \mu^\star)$ be a solution of (7.18). We show that $(\alpha\lambda^\star, \alpha\mu^\star)$ is a solution of (7.18).

$$\begin{aligned}
q(\alpha\lambda^\star, \alpha\mu^\star) &= \inf_{x\in X} \left\{ \sum_{k\in\mathcal{K}} \alpha\lambda_k^\star g_k(x) + \sum_{e\in\mathcal{E}} \alpha\mu_e^\star h_e(x) \right\} \\
&= \inf_{x\in X} \left\{ \alpha \left\{ \sum_{k\in\mathcal{K}} \lambda_k^\star g_k(x) + \sum_{e\in\mathcal{E}} \mu_e^\star h_e(x) \right\} \right\} \\
&\overset{\alpha>0}{=} \alpha \left\{ \inf_{x\in X} \left\{ \sum_{k\in\mathcal{K}} \lambda_k^\star g_k(x) + \sum_{e\in\mathcal{E}} \mu_e^\star h_e(x) \right\} \right\} \\
&= \alpha q(\lambda^\star, \mu^\star) > 0
\end{aligned}$$

□

Inequality (7.19) is a conic combination of the inequality constraints $g_k(x) \leq 0$ plus a linear combination of the equations $h_e(x) = 0$. Thus, (7.19) is the convex optimization analogue of the dual proof constraint (7.4).

Assume that (7.19) is derived as a local infeasibility proof within NLP-based branch-and-bound. Since gradient cuts of convex constraints are globally valid, inequality (7.19) will be a globally valid convex nonlinear constraint.

Obviously, constraint (7.19) holds for all (λ, μ) with $\lambda \geq 0$. What is special about the pair $(\lambda^\star, \mu^\star)$ derived from the nonlinear infeasibility proof; what makes it preferable for creating additional constraints? Consider an infeasible point $x^\star \in X$ and the linearization of g_k and h_e at this point, e.g.,

$$g_k(x^\star) + \nabla g_k(x^\star)^\mathsf{T}(x - x^\star) \leq 0 \quad \Longleftrightarrow \quad \nabla g_k(x^\star)^\mathsf{T} x \leq \nabla g_k(x^\star)^\mathsf{T} x^\star - g_k(x^\star) \; \forall k \in \mathcal{K}.$$

The dual multipliers $\lambda^\star, \mu^\star$ give rise to the Farkas system

$$\begin{aligned} \sum_{k \in \mathcal{K}} \lambda_k^\star \nabla g_k(x^\star) + \sum_{e \in \mathcal{E}} \mu_e^\star \nabla h_e(x^\star) &= 0 \\ \sum_{k \in \mathcal{K}} \lambda_k^\star (\nabla g_k(x^\star)^\mathsf{T} x^\star - g_k(x^\star)) + \sum_{e \in \mathcal{E}} \mu_e^\star \nabla h_e(x^\star)^\mathsf{T} x^\star &< 0. \end{aligned} \tag{7.20}$$

Thus, for every infeasible convex MINLP an LP relaxation can be constructed from which a linear proof of infeasibility can be derived. This could be done by linearizing all nonlinear constraints g_k with $\lambda_k > 0$ at an (arbitrary) infeasible point. However, using a linear dual proof constraint derived from (7.20) will in general be weaker than the nonlinear dual proof (7.19). An illustration of the strength of linear and nonlinear underestimators is given in the following example and Figure 7.1.

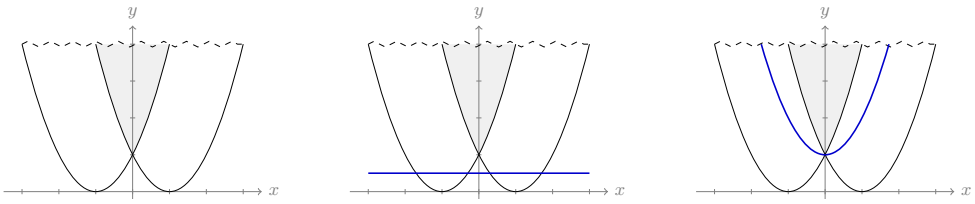
Example 27. *Consider the following convex nonlinear system.*

$$\begin{aligned} g_1(x, y): &\qquad (x-1)^2 - y \leq 0 \\ g_2(x, y): &\qquad (x+1)^2 - y \leq 0 \end{aligned}$$

with $x, y \geq 0$, see Figure 7.1a. Assume we perform a branching $y \leq \frac{1}{2}$, thereby rendering the system infeasible by a local bound change. Then, $\lambda_1 = \lambda_2 = \frac{1}{2}$, together with $\lambda_3 = 1$ for the branching constraint, are valid dual multipliers proving infeasibility. Linearizing g_1 and g_2 at the infeasible point $(0, \frac{1}{2})$ gives

$$2x - y + \frac{1}{2} \leq 0 \quad \text{and} \quad -2x - y + \frac{1}{2} \leq 0.$$

Aggregating both linearizations, see Figure 7.1b, with λ_1, λ_2 yields $-y + \frac{1}{2} \leq 0$ as a linear dual proof constraint. The linear dual proof constraints proves infeasibility for $y < 0.5$. In contrast to that, aggregating both nonlinear constraints g_1 and g_2 yields the nonlinear dual proof constraint $x^2 + 1 - y \leq 0$, see Figure 7.1c. The nonlinear dual proof constraint proves infeasibility for $y < x^2 + 1$, which is stronger than the linear proof.



(a) Feasible region (gray).

(b) Linear dual proof (blue).

(c) Nonlinear dual proof (blue).

Figure 7.1: Illustration of linear and nonlinear dual proofs of Example 27 projected into the y-space.

Constraint (7.19) would have directly given a proof of infeasibility in form of a single inequality. More precisely, if (7.19) had been part of the constraint set, the relaxation would not have to be solved for the current subproblem; instead, infeasibility could have been proven by domain propagation.

It seems to be a reasonable assumption that propagating inequality (7.19) will also help detecting infeasibility or deducing further variable bounds in the remainder of the search. We know from dual proof analysis that this assumption holds for MIP and will test this conjecture for convex MINLP in our computational study. Just as for MIP solving, dual proof constraints and other information derived from infeasibility might also prove useful for other solving techniques, think of hybrid branching (Achterberg and Berthold, 2009), conflict-driven diving heuristics (Chapter 6), and also (local) rapid learning (Chapter 5).

For many NLP solvers, in particular dual active set methods (Murty and Yu, 1988; Nocedal and Wright, 2006; Forsgren et al., 2016) and barrier algorithms (Mehrotra, 1992; Mészáros, 1999; Wächter and Biegler, 2006), dual multipliers will be readily available. The added advantage of active set methods is that they typically yield a sparse dual weight-vector (λ, μ).

7.5 Nonlinear Dual Proofs: Implementation Aspects

In this section, we introduce a dual multiplier filtering heuristic, which proved to be an important detail of our implementation, and we discuss the impact of different types of NLP solvers on the presented algorithms.

7.5.1 Dual Multiplier Filtering Heuristic

Let $(\lambda^\star, \mu^\star) \in \mathbb{R}^{|\mathcal{K}|}_{\geq 0} \times \mathbb{R}^{|\mathcal{E}|}$ be a set of dual multipliers proving infeasibility of (7.12). The support of $(\lambda^\star, \mu^\star)$ is not minimal in general; Every set of dual multipliers $(\overline{\lambda}, \overline{\mu}) \in \mathbb{R}^{|\mathcal{K}|}_{\geq 0} \times \mathbb{R}^{|\mathcal{E}|}$ with $\operatorname{supp}(\lambda^\star) \subseteq \operatorname{supp}(\overline{\lambda})$ and $\operatorname{supp}(\mu^\star) \subseteq \operatorname{supp}(\overline{\mu})$ satisfying (7.18) yields a

(nonlinear) dual proof. Hence, we might be able to obtain a dual proof involving less of the original problem constraints simply by setting some of the dual multipliers to zero. In particular, in some cases it might be possible to remove entire classes of constraints in this fashion.

In our implementation we always try to prefer linear dual proofs over nonlinear ones. One reason for preferring linear constraints is the fast propagation compared to nonlinear constraints in general, i.e., linear time in the number of nonzero variables compared to linear time in the number of expressions. Moreover, quadratic constraints are preferred over general nonlinear. Therefore, we subsequently check whether the following constraints prove infeasibility:

1. $\sum_{e\in\mathcal{E}} \mu_e^\star h_e(x) \leq 0$
2. $\sum_{i\in\mathcal{Q}} \lambda_i^\star g_i(x) + \sum_{e\in\mathcal{E}} \mu_e^\star h_e(x) \leq 0$, where $\mathcal{Q} := \{i \in \mathcal{K} \mid g_i \text{ is quadratic}\}$
3. $\sum_{i\in\mathcal{K}} \lambda_i^\star g_i(x) + \sum_{e\in\mathcal{E}} \mu_e^\star h_e(x) \leq 0$

and immediately stop if we found a valid proof.

Analogous to linear dual proof constraints, nonlinear dual proof constraints are used only for propagation within our implementation.

7.5.2 Interior Point vs. Active Set Methods

The preferred technique for solving the relaxations within an LP-based (spatial) branch-and-bound is the dual Simplex algorithm (Lemke, 1954). Simplex-based LP solvers typically provide the dual multipliers proving local infeasibility. However, the set of dual multipliers returned by the Simplex algorithm is not minimal in general. Note that, calculating a maximally sparse vector of dual multipliers that is sufficient to render infeasibility is strongly $\mathcal{NP}$-hard (Chakravarti, 1994). Such a set of multipliers is well-known as *minimal irreducible infeasible set* (minIIS) (e.g., Chinneck and Dravnieks, 1991; Gleeson and Ryan, 1990).

Similar to LP solvers, dual multipliers are readily available in many NLP solvers. This holds in particular for *dual active set methods* (e.g., Murty and Yu, 1988; Nocedal and Wright, 2006; Forsgren et al., 2016) and barrier algorithms (e.g., Mehrotra, 1992; Mészáros, 1999; Wächter and Biegler, 2006). Active set methods often give comparably sparse dual weight-vectors (λ, μ). Intuitively, one would expect that a sparse vector of dual multipliers might lead to nonlinear dual proofs with a smaller support. Of course, this intuition is not true in general but it is worthwhile to investigate whether active set methods lead to nonlinear dual proofs that are more efffective than those generated with a dense vector of multipliers, like it is the case for barrier algorithms. We support both types of NLP solvers within our implementation and compare their impact on dual proof analysis as part of our computational study.

7.6 Computational Results

In our computational study, we address three questions:

- When solving general MINLPs with an LP-based branch-and-bound, what is the impact of using a combined approach of applying (global) dual proof analysis in addition to conflict graph analysis?
- Given that local linearization cuts often prohibit finding globally valid proof constraints: What is the impact of our suggested strategy to generate local dual proofs when solving nonconvex MINLPs with an LP-based branch-and-bound?
- When solving general MINLPs with an NLP-based branch-and-bound approach, what is the impact of our newly proposed nonlinear dual proofs?

In order to answer these three questions, we carried out an extensive computational study. In the first part of this section, we analyze the impact of LP-based conflict analysis in SCIP within an LP-based branch-and-bound. To do so, we compare SCIP without LP-based conflict analysis (`nolpinf`) against SCIP using conflict graph analysis solely (`confgraph`), and SCIP using a combined approach of conflict graph analysis and dual proof analysis (`combined`).

In the second part of this section, we compare `nolpinf` with `combined` and an extension of `combined` that exploits locally valid dual proof constraints. We refer to the latter as `combined-local`. Note again that for convex MINLPs, all proof constraints are globally valid. Consequently, this part of the study is only conducted for nonconvex MINLPs.

In the last part of this section, we present computational results on the impact of nonlinear dual proof constraints. Based on an NLP-based branch-and-bound, we compare SCIP without conflict analysis (`noconflict`) to SCIP applying conflict graph analysis to infeasibilities derived during constraint propagation (`nonlpinf`). Further, we compare both settings to SCIP deriving nonlinear dual proof constraints from infeasible convex NLP relaxations (`nlpinf`).

Note that, we are not addressing the question which relaxation performs better within a branch-and-bound. Similar questions have been addressed in other papers, notably Kılınç and Sahinidis (2017) conducted an intense computational study on using different relaxations for solving MINLPs with BARON.

All experiments were performed with the academic solver SCIP (git hash fd3e45275d, based on SCIP 6.0.2) (Gleixner et al., 2018). For the results presented in Sections 7.6.1 and 7.6.2, we used SoPlex 4.0.0 as LP solver. For the results presented in Section 7.6.3, we used Ipopt 3.12.11 (Wächter and Biegler, 2006) and FilterSQP (Fletcher and Leyffer, 1998) as NLP solvers.

We use IPET[8] for our data analysis. We ran the experiments on a cluster of identical machines equipped with Intel Xeon E5-2690 CPUs with 2.6 GHz and 128 GB of RAM; a time limit of 7200 seconds was set. We conducted all experiments with three different random constraint permutations of each instance to mitigate the impact of performance variability (Lodi and Tramontani, 2013). We used MINLPLIB[9] as a test set, excluding instances that are purely continuous, i.e., do not contain any integer variables. This test set consists of 1029 publicly available MINLP problems. Every combination of MINLP problem and permutation is treated as an individual observation. This gives us 3087 instances in our test set. Further on, the term "instance" refers to a particular permutation of a problem.

All tables in the remainder of this section contain aggregated results. Detailed results with instance-wise computational results can be found in a GitHub repository[10]. Note that for every table we excluded instances that either could be solved at the root node by all settings or for which at least one setting came up with a solution that violates constraints, integrality or optimality by more than SCIP's standard numerical thresholds.

The tables in this chapter distinguish between instances for which every considered setting hit the time limit (timelimit) and instances that could be solved by at least one considered setting (1-opt). The set 1-opt is further divided into affected instances and into a hierarchy of increasingly harder classes "$\geq k$". We call an instance affected when it did not take the same solution path for all settings of the respective table. Class "$\geq k$" contains all affected instances for which at least one setting needed at least k seconds. Thus, "≥ 1000" $\subseteq$ "≥ 100" $\subseteq$ "≥ 10" $\subseteq$ "affected". Consequently, the difference between "affected" and "≥ 10" constitutes the number of models that solve in less than 10 seconds by all methods. This is an unbiased method to exclude instances which are trivial to solve for all variants, see also (Achterberg and Wunderling, 2013). Moreover, if both convex and nonconvex MINLPs are considered, the respective table distinguishes between convex and nonconvex affected instances.

For every group of instances the tables show:

- the number of instances in the respective group (2^{nd} column: #),
- the number of solved instances (**S**)
- the shifted geometric mean of run time, where a shift of 1 was used (**T**)
- the relative run time with respect to the baseline setting ($\mathbf{T_Q}$)
- the shifted geometric mean of tree nodes, where a shift of 100 was used (**N**)

[8] https://github.com/GregorCH/ipet
[9] http://www.minlplib.org/, git hash a71254dc
[10] https://github.com/jakobwitzig/conflict-analysis-minlp

- the relative number of tree nodes with respect to the baseline setting ($\mathbf{N_Q}$)
- the dual integral with respect to the best know primal solution (**DI**)
- the relative dual integral with respect to the baseline setting ($\mathbf{DI_Q}$)

Relative solving times of setting s are defined by the quotient t_s/t_b, where t_s is the geometric mean solving time of setting s and t_b is the geometric mean solving time of setting b that is used as a baseline. An analogous definition holds for the dual integral and for the explored branch-and-bound nodes. Thus, a number less than one implies that the setting s is superior and a number greater than one implies that it is inferior to the baseline setting b. In the following tables, an improvement or deterioration by at least 5 % is highlighted in bold and blue or italic and red, respectively.

The dual integral measures the progress of the dual bound's convergence towards the optimal (or best-known) solution over the entire solving time and is defined analogously to the primal integral (Berthold, 2013).

The (relative) number of nodes is computed over the set of instances that could be solved by all settings. For the group 1-opt, 1376 out of 1403 (Table 7.1), 606 out of 632 (Table 7.2), and 598 out of 626 (Table 7.3) fulfilled this criterion.

7.6.1 LP-based Conflict Analysis

In this section, we address our first question of what the impact of LP-based conflict analysis is when solving MINLPs with an LP-based branch-and-bound. Table 7.1 summarizes our findings. It compares three different settings: `nolpinf` for a version of SCIP that does not use LP-based conflict analysis, `confgraph` for a version of SCIP that applies conflict graph analysis to infeasible LP relaxations, and `combined` for a version of SCIP that uses dual proof analysis in addition to conflict graph analysis for infeasible LPs. The setting `confgraph` is the default setting of SCIP and corresponds to what has been used by Vigerske and Gleixner (2018), which to the best of our knowledge is the only computational study of conflict analysis techniques for MINLP so far.

Our results confirm the findings of the named paper that the impact of conflict graph analysis on the overall running time is marginal, yet slightly positive. Not surprisingly, the technique works better on the subset of convex MINLPs, a distinction the authors did not consider. Our results indicate that applying dual proof analysis in addition to conflict graph analysis is beneficial. We observed an overall speedup of 3 %, with speedups of 8 % and more on instances that take more than 100 seconds, more than 1000 seconds to solve, and on the subset of convex MINLPs. This goes hand in hand with a significant reduction of the average search tree size and an improvement in the dual integral of more than 10 % for many subsets that we considered. Notably, also for

Table 7.1: Impact on LP-based branch-and-bound when using a combined approach of dual proof and conflict graph analysis: aggregated computational results on MINLP.

		nolpinf				confgraph				combined			
	#	**S**	**T**	**N**	**DI**	**S**	$\mathbf{T_Q}$	$\mathbf{N_Q}$	$\mathbf{DI_Q}$	**S**	$\mathbf{T_Q}$	$\mathbf{N_Q}$	$\mathbf{DI_Q}$
1-opt	1403	1387	15.64	1463	895	1386	0.991	1.001	0.952	**1394**	0.970	0.963	0.954
timeout	1022	0	7200.00	–	231626	0	1.000	–	0.959	0	1.000	–	**0.929**
affected	908	892	31.04	4431	1606	891	0.988	1.002	**0.930**	**899**	0.956	**0.945**	**0.933**
≥ 10	553	537	148.40	22441	4743	536	0.979	0.975	**0.893**	**544**	**0.933**	**0.911**	**0.899**
≥ 100	295	279	646.17	129365	22502	278	0.981	0.991	**0.842**	**286**	**0.920**	**0.936**	**0.852**
≥ 1000	131	115	2173.90	422656	75451	114	1.003	1.005	**0.746**	**122**	**0.910**	0.968	**0.804**
convex	485	483	17.67	3834	1269	483	0.951	0.984	**0.855**	483	**0.917**	**0.913**	**0.867**
nonconvex	423	409	58.52	5269	2096	408	1.030	1.025	1.020	**416**	0.999	0.984	1.012

the set of instances that timed out with all settings, we observed an improvement in the dual integral by about 7 %.

Similar to what is known from solving MIPs, our results indicate that conflict analysis for MINLPs works especially well for infeasible instances and feasibility instances, i.e., for instances where the tree is not pruned by bounding with respect to an incumbent solution. For such instances, we observed an above average speedup of 24 % (`confgraph`) and 38 % (`combined`) compared to `noconflict`. However, this group of instances forms a rather small part of our test set (33 in 1-opt, 14 affected).

As expected, for nonconvex MINLPs, the technique is almost performance-neutral. Globally valid proofs could rarely be constructed, therefore the benefit on a few instances is compromised by a slight computational overhead on many instances. It is worth mentioning that we could solve eight more nonconvex MINLPs when using dual proof analysis.

7.6.2 LP-based Local Dual Proofs

In this section, we address our second question of what the impact of generating local dual proofs is when solving nonconvex MINLPs with an LP-based branch-and-bound. Table 7.2 depicts our results. Columns `nolpinf` and `combined` take the same meaning as before, Column `combined-local` shows the performance of a version that generates both, conflict constraints and dual proof constraints that are allowed to be locally valid. We see that for harder instances, the impact of standard conflict analysis is even slightly negative. In marked contrast, employing local dual proofs for nonconvex MINLPs led to a performance improvement with respect to the overall running time on all subset of instances that we considered. The overall impact was about 2.5 % speedup. For instances that need more than 1000 seconds to solve, the difference was most pronounced, but given the small size of this subset, the result should be taken with a grain of salt. The slight deterioration in the number of nodes is due to a single outlier instance which creates a significantly larger search tree while taking only twice

Table 7.2: Impact of using local dual proof within LP-based branch-and-bound: aggregated computational results on the subset of nonconxex instances of MINLP.

		nolpinf				combined				combined-local			
	#	**S**	**T**	**N**	**DI**	**S**	$\mathbf{T_Q}$	$\mathbf{N_Q}$	$\mathbf{DI_Q}$	**S**	$\mathbf{T_Q}$	$\mathbf{N_Q}$	$\mathbf{DI_Q}$
1-opt	632	614	31.62	2123	1150	621	0.998	0.985	1.009	**623**	0.975	0.964	1.004
timeout	862	0	7200.00	–	226311	0	1.000	–	**0.923**	0	1.000	–	**0.932**
affected	441	423	58.63	5227	2065	430	0.997	0.979	1.012	**432**	0.965	**0.949**	1.006
$\geq$ 10	309	291	191.87	15244	5884	298	1.005	0.999	1.021	**300**	0.959	0.954	1.013
$\geq$ 100	179	161	736.74	68520	22734	168	1.045	*1.113*	1.047	**170**	0.963	1.030	1.034
$\geq$ 1000	80	62	2593.38	167820	74290	69	1.018	*1.163*	1.036	**71**	**0.877**	1.013	0.965

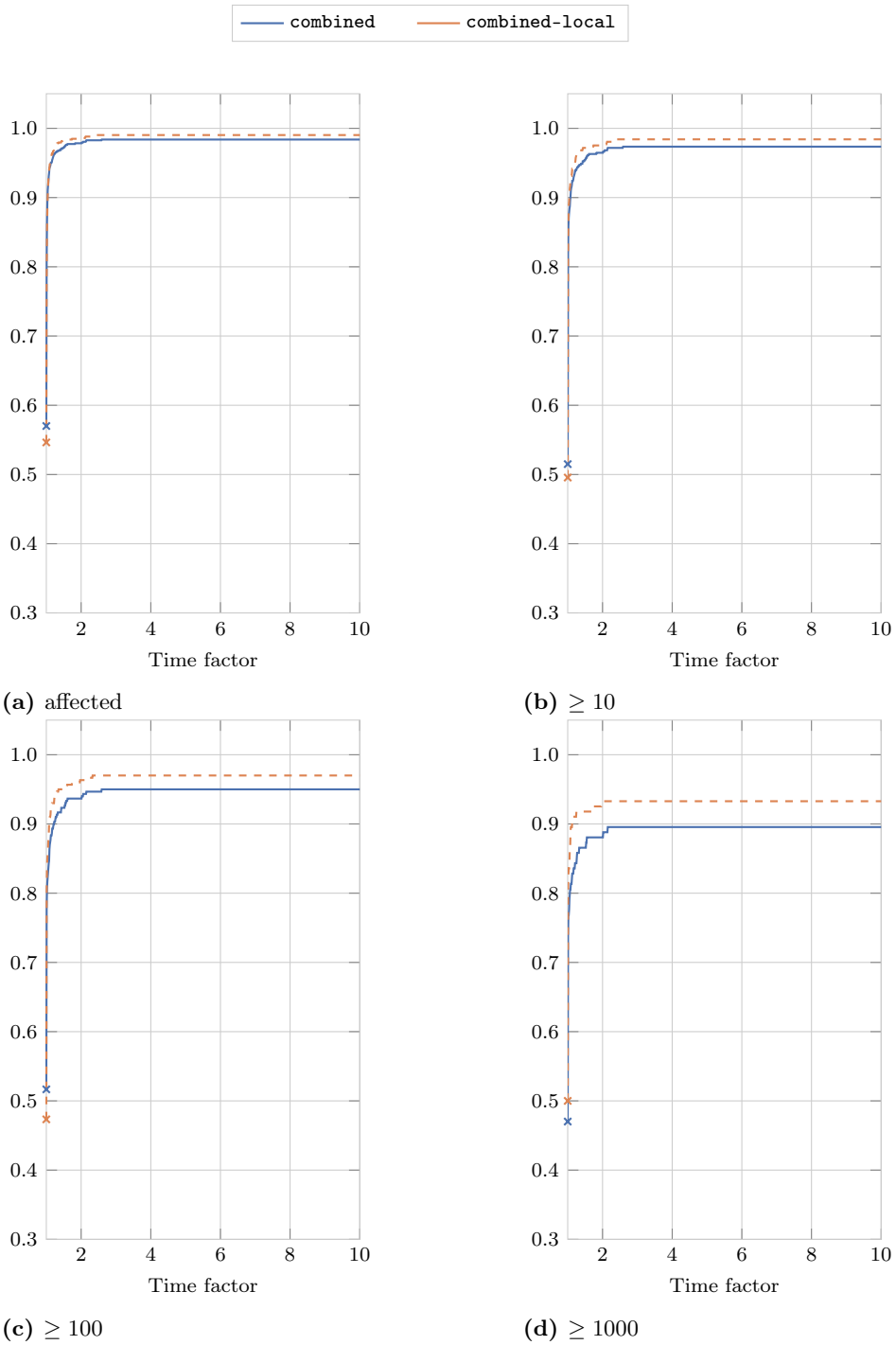
as much run time.

The impact on the number of branch-and-bound nodes is roughly similar to the impact on running time. The dual integral, however, seems to be hardly affected. This can partially be explained by this technique being local and thereby only affecting the part of the tree that is currently being processed. In classical conflict analysis, the generation of new globally valid constraints might, e.g., trigger an immediate reduction of global variable bounds by propagating the new constraints, which in turn might raise the global (not only the local) dual bound. It should be said, though, that on the set of instances that timed out with all settings, we did observe an improvement for the dual integral.

Figure 7.2 shows performance profiles (Dolan and Moré, 2002) for the set of affected instances and all "$\geq k$" brackets for $k \in \{10, 100, 100\}$. We compare the two settings `combined` and `combined-local`. See Gould and Scott (2016) why one should take caution when including more than two settings within a single performance profile. In all four profiles, the version using local dual proofs is consistently superior to the version without. This indicates that a) the improvement is independent of the intrinsic difficulty of the model (since the observation holds across all brackets) and b) independent of the magnitude of impact local dual proofs have (since the difference is almost constant over the time factor axis). Further, the performance profiles confirm our observation, that the performance gain achieved by local dual proof is more pronounced on harder instances. Overall, our results give a strong indication that the generation of local infeasibility proofs for nonconvex MINLPs is beneficial.

Figure 7.3 visualizes the effect of lifting locally valid dual proofs, in an instance-wise manner. For every nonconvex MINLP in our test set where at least 50 infeasible LP relaxations were encountered (1142 instances) we analyzed the reduction of depth at which the dual proof is valid. More precisely, for each instance we calculated the following three percentages:

- The portion of dual proofs for which at least one linearization cut that is only valid at the current node is needed to prove infeasibility (group "local"). For such



(a) affected

(b) ≥ 10

(c) ≥ 100

(d) ≥ 1000

Figure 7.2: Performance profiles of `combined` and `combined-local` for four hierarchical groups of increasingly harder, affected instances.

proofs, no depth reduction is possible and they have to be discarded.

- The portion of dual proofs for which no locally valid linearization cut is needed (group "global"). These proofs are globally valid and can be lifted to the root node. Hence, they can be used for propagation throughout the remainder of the search.

- The portion of dual proofs for which at least one local linearization cut is needed, but none from the current node. These proofs are locally valid at some ancestor of the current node, but not at the root. They can be used for searching parts of the tree which share that ancestor and are therefore added as locally valid constraints to the named ancestor node. (group "liftd").

For each group the figure shows a box-plot (McGill et al., 1978), where the box ranges indicates the second and the third quartile. The median is marked with a bold, horizontal solid line, each instance outside the box is indicated by a dot.

The left box plot shows that it is a common case that most proofs are only locally valid and, therefore, have to be discarded. The median bar is at 77 %, which means that for half of the considered instances, we could not lift the generated dual proof for at least 77 % of all analyzed infeasible LPs. For 25 % of the instances, this share was even larger than 93 %. Note, however, that the 75 %-percentile is comparably low, at 5 %.

The right box plot shows that the next common case is proofs being globally valid. For 25 % of the instances, more than 82 % of the proofs could be lifted to the root node. The median is at 4 %, which means that for 50 % of the instances, at least 4 % of the proofs could be lifted to the root. On 35 % of the instances, we observed that no globally valid proof could be derived at all.

The middle box plot finally demonstrates two things. Firstly, it shows that some form of lifting to an inner node is possible in a majority of instances, though typically not for a large share of proofs. For half of the instances, at least 2 % of the proofs could be lifted to an inner node and for 25 % of the instances, at least 8 % of the proofs could be lifted. Secondly, we observe that the outlier dots are all over the place. There are various instances for which a large share of dual proofs can be lifted to inner nodes.

7.6.3 NLP-based Conflict Analysis

In this section, we address our third and final question of what the impact of generating nonlinear dual proofs is when solving MINLPs with an NLP-based branch-and-bound. Table 7.3 presents, to the best of our knowledge, the first computational results for applying conflict analysis within an NLP-based branch-and-bound algorithm. We show three different settings: `noconflict` for a version of SCIP that does not use any form of

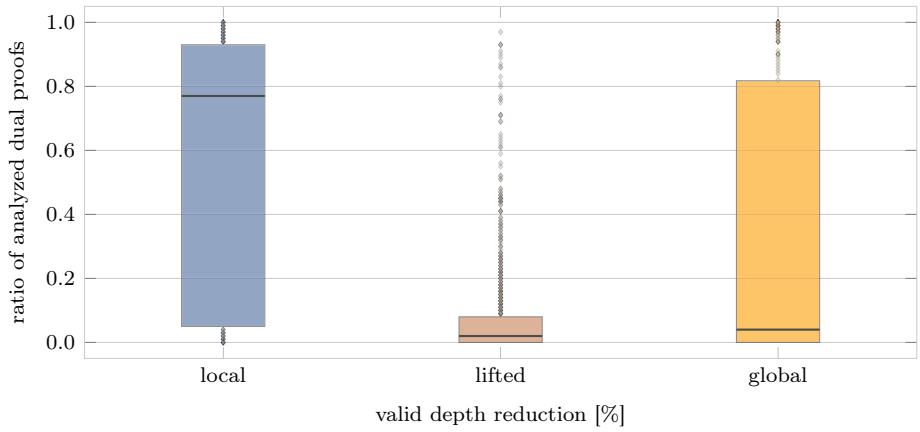


Figure 7.3: Instance-wise distribution dual proof constraints that are only locally valid at the node where they have been created, constraints that can be lifted to an inner node of the search tree, and constraints that are globally valid.

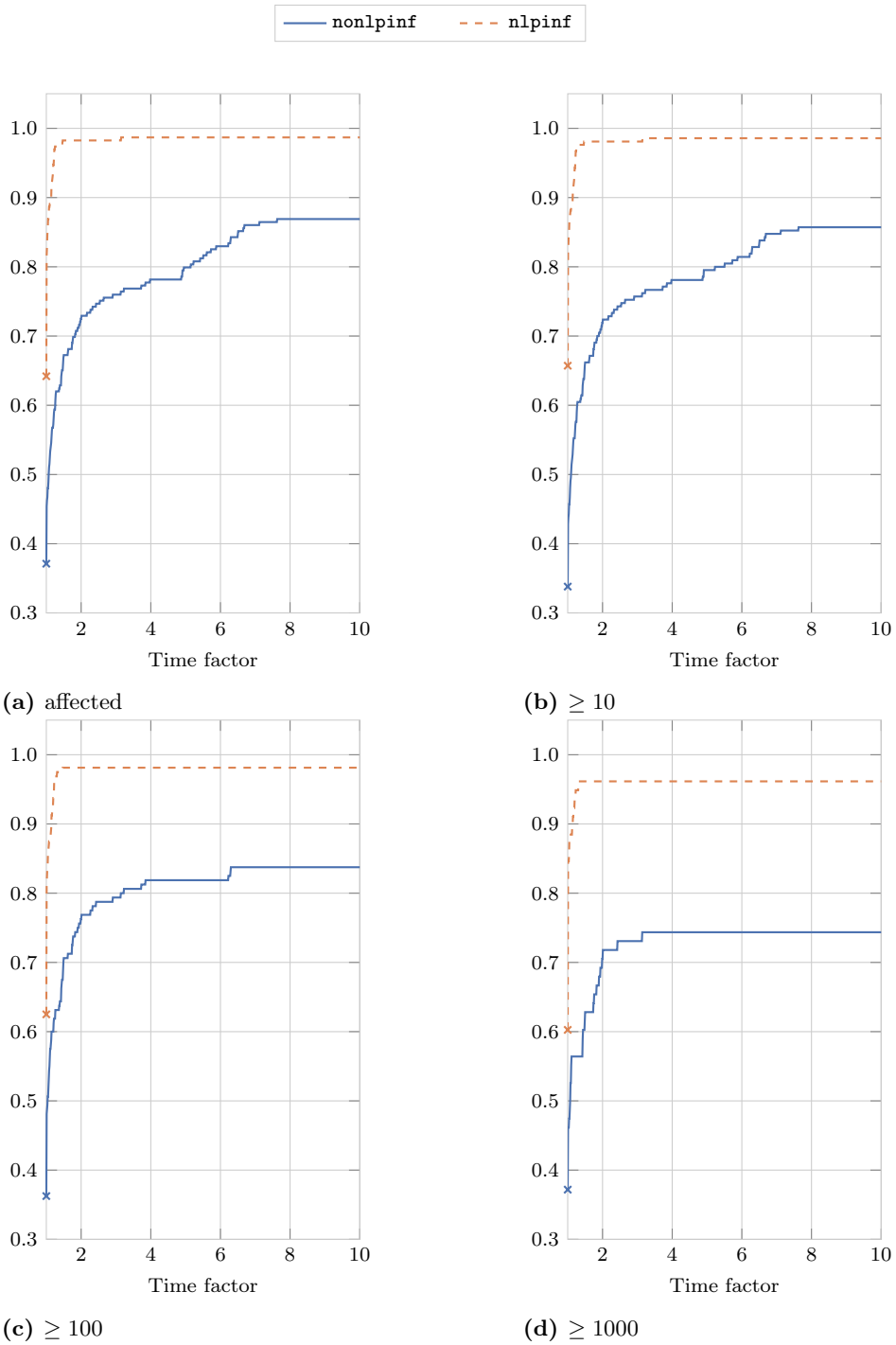
conflict analysis, `nonlpinf` for a version of SCIP that applies conflict graph analysis to infeasibilities found by domain propagation, and `nlpinf` for a version of SCIP that in addition uses dual proof analysis for infeasible NLPs. In addition, we show performance profiles for the affected instances and all brackets in Figure 7.4.

For the experiments in this section, we extended SCIP to work as an NLP-based branch-and-bound solver, using IPOPT as NLP solver. In our implementation, we always solve a convex NLP relaxation of the possibly nonconvex MINLP. The convex NLP relaxation consists of all linear constraints, non-linear constraints that are recognized by SCIP to be convex, and linear underestimators of nonconvex constraints. Due to the plugin-based design of SCIP, a lot of the functionality could easily be inherited from the LP-based implementation. For example, the NLP-based solver features a fully-fledged presolving algorithm, advanced domain propagation/bound tightening procedures and involved branching rules based on pseudo-costs and other history information. However, some functionality is still missing in this prototype implementation, e.g., the separation of combinatorial cutting planes, or an NLP-equivalent to reduced cost fixing. Furthermore, while the LP-based branch-and-bound has undergone years of solver parameter fine-tuning, this does not hold true for our new NLP-based branch-and-bound implementation. Consequently, it can be expected that the results are somewhat more pronounced than for the LP-based case.

Nevertheless, the extent of this distinction came as a surprise to us. First of all, we see that conflict graph analysis from infeasibilities found in domain propagation already has a significant impact. It leads to an overall speedup of more than 6 % and shows consistent improvements throughout the board for all our performance measures. The generation of nonlinear dual proofs from infeasible NLP relaxations excels. It reduces

Table 7.3: Impact of nonlinear dual proofs on NLP-based branch-and-bound: aggregated results on MINLP.

		noconflict				nonlpinf				nlpinf			
	#	**S**	**T**	**N**	**DI**	**S**	**T_Q**	**N_Q**	**DI_Q**	**S**	**T_Q**	**N_Q**	**DI_Q**
1-opt	626	601	66.02	505	1303	608	**0.937**	**0.948**	**0.950**	**623**	**0.766**	**0.887**	**0.877**
timeout	1660	0	7200.00	–	324698	0	1.000	–	**0.916**	0	1.000	–	**0.910**
affected	229	205	286.84	1529	3807	211	**0.839**	**0.870**	**0.875**	**226**	**0.488**	**0.729**	**0.712**
$\geq$ 10	210	186	426.86	1987	4899	192	**0.827**	**0.860**	**0.866**	**207**	**0.467**	**0.716**	**0.693**
$\geq\geq$ 100	160	136	1018.40	3842	6909	142	**0.789**	**0.826**	**0.834**	**157**	**0.466**	**0.708**	**0.644**
$\geq$ 1000	78	54	3197.11	9095	11166	60	**0.759**	**0.852**	**0.771**	**75**	**0.404**	**0.741**	**0.478**
convex	151	135	240.21	1132	5864	135	0.995	0.999	1.003	**151**	**0.453**	**0.806**	**0.751**
nonconvex	78	70	404.29	2756	1622	**76**	**0.604**	**0.664**	**0.659**	75	**0.563**	**0.599**	**0.633**



(a) affected

(b) ≥ 10

(c) ≥ 100

(d) ≥ 1000

Figure 7.4: Performance profiles of `nonlpinf` and `nlpinf` for four hierarchical groups of increasingly harder, affected instances.

the overall running time by more than 20 %, cutting it down to less than half on the set of affected instances.

The results for the number of nodes and the dual integral are not as extreme, but still more than 20 % in all subsets. On the set of instances where all methods timed out, the dual integral improved by 9 %. For all cases shown in the performance profiles (see Figure 7.4), using nonlinear dual proofs is clearly superior, independent of the time factor. We see that the `nlpinf` line is almost flat and close to 1.0. This shows that, while there are a few instances which could not be solved when using nonlinear conflicts, it is dominating the `nonlpinf` setting on almost every instance. There are hardly instances which solve with both variants, but `nlpinf` is slower.

Altogether, our results give clear evidence that the generation of nonlinear dual proofs helps to improve the performance of such algorithms.

In our implementation, we prefer linear infeasibility proofs derived from the nonlinear relaxation over quadratic infeasibility proofs and quadratic over general nonlinear infeasibility proofs, as described in Section 7.5.1. The set of instances that are affected by this dual multiplier filtering heuristic is comparably small, containing 75 instances. On this set of affected instances, however, we observe a clear performance improvement caused by the named heuristic. All three performance measures, the running time, the number of nodes and the dual integral, reduce significantly by 8 %, by 2 % and by 14 %, respectively.

Finally, we made an additional experiment to investigate the impact of different NLP solving algorithms on the density of dual proofs as described in Section 7.5.2. The box plots in Figure 7.5 show that, as expected, the dual solutions generated by the active set method are much sparser than the ones from the interior point solver. When using an interior point solver, the average density of the dual solutions is larger than 40 % for half of the instances for bound-exceeding proofs and larger than 32 % for half of the instances for infeasibility proofs. When using an active set method, the median was at 16 % and 9 %, respectively. Consequently, the speedup achieved by dual proof analysis was slightly larger when using an active set method, but only in the range of one to two percent.

7.7 Conclusion

In this chapter, we studied different ways to learn from infeasible subproblems when solving MINLPs. More precisely, we studied the impact of two different techniques – conflict graph analysis and dual proof analysis – and two different solution paradigms – LP-based branch-and-bound and NLP-based branch-and-bound – for convex and nonconvex MINLPs. Conflict graph analysis for MINLP has been previously described in the literature and shown to be of little impact. Although the generalization of dual

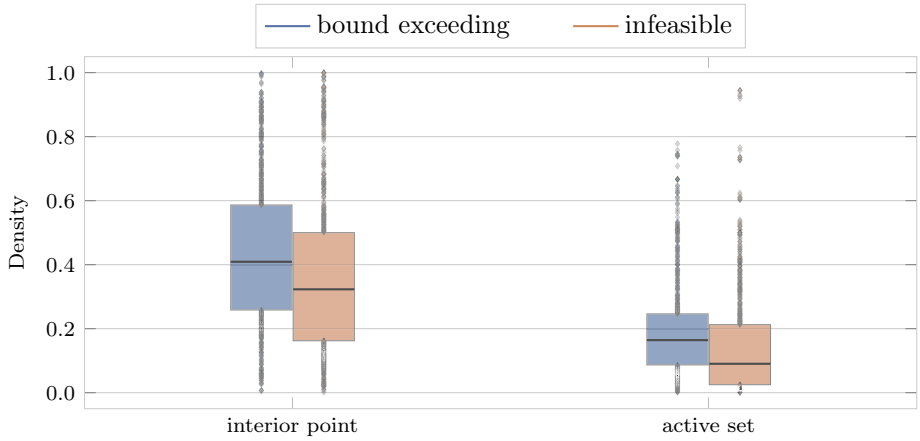


Figure 7.5: Instance-wise distribution of the density of constraints contributing to a dual proof constraint.

proof analysis to LP-based branch-and-bound for MINLP is straight-forward, it has, to the best of our knowledge, not been studied before. We introduced a novel technique, lifting of local dual proofs for nonconvex MINLPs, and showed that a combination of conflict graph analysis and dual proof analysis lead to a speedup of more than 8 % for convex MINLPs and 4.5 % for nonconvex MINLPs in a state-of-the-art LP-based branch-and-bound solver.

The other main contribution of the chapter is a generalization of dual proof analysis to NLP-based branch-and-bound for MINLP. We showed how to derive globally valid nonlinear constraints from the dual solution of a convex NLP relaxation of a local subproblem, using a variant of Farkas' lemma based on KKT conditions. When implementing this technique within an NLP-based branch-and-bound solver, we observed a speedup of more than 20 %. Our results clearly indicate that the analysis of infeasible subproblems plays an important role for the performance of global MINLP solvers and constitutes an interesting field of research.

Chapter 8

Conclusion

This thesis focused on conflict analysis in mixed integer programming (MIP) and mixed integer nonlinear programming (MINLP). In the preceding chapters, we investigated many different aspects of conflict analysis in MIP. Firstly, we discussed the connection of conflict graph analysis and dual proof analysis; followed by demonstrating that a general-purpose MIP solver such as SCIP benefits from implementing both techniques and using them simultaneously. Secondly, we demonstrated that a general purpose MIP solver such as SCIP significantly benefits when increasing the effort spent in generating information about infeasible subproblems. In this thesis, we enhanced existing methods and developed new methods that explicitly aim to generate and exploit additional conflict information. Moreover, we demonstrated that it is worthwhile to learn from parts of the search tree that are close to be infeasible. Finally, we advanced conflict analysis to general MINLP: Local dual proof constraints within an LP-based branch-and-bound and nonlinear dual proof constraints within an NLP-based branch-and-bound.

The main contributions and results of this thesis are as follows.

1. In Chapter 3, we investigated three enhancements of dual proof analysis and demonstrated that SCIP benefits fom using a combined approach of conflict graph analysis and dual proof analysis. In a thorough computational study, we showed that the simultaneous use of both techniques speeds up the solving process by 28 % (group: $\geq$ 100s) compared to using any of the techniques individually within SCIP.

2. In Chapter 4, we focussed on infeasibility induced by LP relaxations exceeding the cutoff bound. We generalized dual proof analysis to so-called conflict-free dual proofs and demonstrated that applying conflict analysis to not-yet infeasible subproblems improves the solving time of SCIP by 6 % (group: $\geq$ 100s) on mixed

binary programs.

3. In Chapter 5, we generalized an existing technique called RAPID LEARNING from binary programs to general integer programs. Moreover, we evolved RAPID LEARNING from a technique that is applied only once to the global problem to a technique that can be beneficially used during the tree search while keeping the computational overhead under control. To achieve this, we identified problem-specific criteria, such as degeneracy, that allow us to decide dynamically whether and when it is worthwhile to apply RAPID LEARNING during the tree search. Our computational study showed an improvement in terms of running time by 12 % (group: $\geq$ 100s) when applied to integer programs within SCIP.

4. In Chapter 6, we developed two new diving heuristics. The first heuristic, called FARKAS DIVING, explicitly aims for generating additional conflict information by diving towards a valid Farkas proof. The second heuristic, called CONFLICT DIVING, mainly relies on conflict information for the guidance of the search. This heuristics reuses all conflict information generated by the techniques presented in Chapters 3 – 5 and FARKAS DIVING. With this strategy, CONFLICT DIVING pursues a fail-fast strategy, i.e., either infeasibility is encountered fast while saving computing time or solutions are found within regions of the search space that is not searched by other heuristics implemented in SCIP. Our in-depth computational study demonstrated that both heuristics led to a reduction of solving time by 14 % and 6 %, respectively (both on group group: $\geq$ 100s).

5. In Chapter 7 we improved the performance of SCIP for solving MINLPs in two different ways. Firstly, we developed the concept of local dual proof constraints incorporating locally added linearization cuts for nonconvex MINLPs within an LP-based branch-and-bound method. Secondly, we developed the theory of nonlinear dual proofs and extended SCIP by a fully-fledged NLP-based branch-and-bound from which nonlinear dual proof constraints can be derived. Both investigations led to substantial improvements of SCIP in terms running time. Our thorough computational study showed that the solving time of SCIP using an LP-based branch-and-bound method could be reduced by 8 % (group: $\geq$ 100s). When using an NLP-based branch-and-bound method and exploiting nonlinear dual proofs the solving time could be reduced by 41 % (group: $\geq$ 100s).

In this thesis, we shed light infeasibility analysis in MIP from different perspectives: the core techniques of infeasibility analysis, the exploitation of infeasibility information, and generalizations. The presented results emphasize the importance of learning from infeasibility within a general purpose MIP solver.

To come back to Winston Churchill: All search strategies make mistakes, but only conflict-driven strategies learn from their mistakes.

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Appendix A

Computational Aspects of Infeasibility Analysis in MIP

This chapter presents detailed computational results of the experiments discussed in Chapter 3.

- Table A.1 illustrates the overall impact of conflict graph analysis (`confgraph`), dual proof analysis (`dualproof`), and a simultaneous approach using both techniques (`combined`). Baseline is SCIP without any of these techniques (`nolpinf`).
- Table A.2 illustrates the impact of the bound cancellation method described in Section 3.3.1.1. The table shows the number of calls (#**BC**) and cancelled variables (**BC**).
- Table A.3 illustrates the impact of the variable bound cancellation method described in Section 3.3.1.1. The table shows the number of calls (#**VBC**), changed coefficients (**cVBC**), and cancelled variables (**dVBC**).
- Table A.4 illustrates the update scheme described in Section 3.3.1.2. The table shows the number of improving solutions found (**I**), i.e., the number of updates, and the number of updated constraints (**Upd**).
- Table A.5 illustrates the cMIR procedure described in Section 3.3.2. The table shows the number of added cMIR-based dual proofs (**MIR**) and the average of relative density compared to the initial dual proof ($\mathbf{MIRnnz_Q}$).
- Table A.6 illustrates the filtering scheme described in Section 3.3.3. The table shows the number of filtered dual proofs due to numerical properties (**Fn**) and density (**Fl**).

Table A.1: Detailed computational results on MIPLIB 2017 benchmark. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
30n20b8	270.17	314	268.76	0.995	225	**0.717**	150.59	**0.557**	171	**0.545**	149.68	**0.554**	171	**0.545**
	2040.89	7991	1228.78	**0.602**	3940	**0.493**	544.01	**0.267**	1286	**0.161**	623.60	**0.306**	1999	**0.250**
	74.75%	61015	0.00%	1.000	33226	0.545	1350.91	**0.188**	3345	**0.055**	693.56	**0.096**	3499	**0.057**
50v-10	1.43%	1029819	1.28%	1.000	862668	0.838	1.57%	1.000	1050474	1.020	1.69%	1.000	829421	0.805
	1.33%	1066193	1.27%	1.000	1070962	1.004	1.29%	1.000	914227	0.857	1.15%	1.000	867997	0.814
	1.53%	1064237	1.48%	1.000	1081273	1.016	1.26%	1.000	989821	0.930	1.37%	1.000	833134	0.783
CMS750_4	0.40%	545243	0.00%	1.000	418086	0.767	192.32	**0.027**	2622	**0.005**	185.73	**0.026**	2028	**0.004**
	1691.51	63058	1238.90	**0.732**	44234	**0.701**	371.44	**0.220**	2805	**0.044**	370.72	**0.219**	3254	**0.052**
	1368.90	50759	363.74	**0.266**	8870	**0.175**	505.84	**0.370**	12259	**0.242**	473.12	**0.346**	13518	**0.266**
academictimetablesmall	∞	4126	∞	1.000	2655	0.643	∞	1.000	2449	0.594	∞	1.000	2315	0.561
	∞	3330	∞	1.000	1739	0.522	∞	1.000	3047	0.915	∞	1.000	3505	1.053
	∞	2413	∞	1.000	2564	1.063	∞	1.000	2696	1.117	∞	1.000	2681	1.111
air05	40.11	985	39.77	0.992	985	1.000	39.52	0.985	648	**0.658**	40.07	0.999	648	**0.658**
	30.60	465	31.23	1.021	465	1.000	35.63	*1.164*	716	*1.540*	36.54	*1.194*	716	*1.540*
	31.76	321	33.72	*1.062*	432	*1.346*	31.16	0.981	282	**0.879**	30.22	0.952	282	**0.879**
app1-1	2.87	2	3.50	*1.220*	2	1.000	3.52	*1.226*	2	1.000	3.53	*1.230*	2	1.000
	4.61	6	4.80	1.041	3	**0.500**	4.78	1.037	3	**0.500**	4.94	*1.072*	3	**0.500**
	2.97	2	3.70	*1.246*	2	1.000	3.80	*1.279*	2	1.000	4.17	*1.404*	6	*3.000*
app1-2	816.08	52	709.34	**0.869**	22	**0.423**	735.09	**0.901**	30	**0.577**	642.80	**0.788**	33	**0.635**
	781.66	46	638.65	**0.817**	18	**0.391**	730.11	**0.934**	25	**0.543**	789.47	1.010	20	**0.435**
	654.39	22	588.01	**0.899**	16	**0.727**	768.86	*1.175*	24	*1.091*	618.36	**0.945**	20	**0.909**
assign1-5-8	4.67%	6944258	4.64%	1.000	6976961	1.005	4.60%	1.000	6705667	0.966	4.74%	1.000	5736357	0.826
	4.53%	7117474	4.50%	1.000	5922413	0.832	4.49%	1.000	5910141	0.830	4.54%	1.000	6813236	0.957
	4.48%	6558466	4.99%	1.000	6649476	1.014	4.50%	1.000	5865668	0.894	4.80%	1.000	6333262	0.966
atlanta-ip	7.26%	15795	8.05%	1.000	13912	0.881	3.98%	1.000	14873	0.942	3.60%	1.000	18533	1.173
	7.68%	13371	4.53%	1.000	13738	1.027	8.24%	1.000	15611	1.168	3.81%	1.000	21153	1.582
	7.22%	22708	4.29%	1.000	18551	0.817	7.55%	1.000	24254	1.068	4.27%	1.000	30903	1.361
b1c1s1	14.85%	40958	17.39%	1.000	41821	1.021	14.90%	1.000	45138	1.102	17.13%	1.000	35962	0.878
	21.56%	10481	16.28%	1.000	13339	1.273	18.37%	1.000	22683	2.164	18.36%	1.000	21112	2.014
	17.51%	19938	17.19%	1.000	23008	1.154	16.65%	1.000	20087	1.007	17.69%	1.000	18673	0.937
bab2	1.90%	3888	1.33%	1.000	3638	0.936	∞	1.000	3856	0.992	1.29%	1.000	3473	0.893
	∞	3117	0.83%	1.000	3459	1.110	∞	1.000	3397	1.090	2.44%	1.000	3262	1.047
	∞	1764	∞	1.000	1742	0.988	∞	1.000	1981	1.123	∞	1.000	1981	1.123

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
bab6	0.46%	3313	∞	1.000	4902	1.480	∞	1.000	5608	1.693	0.58%	1.000	4790	1.446
	0.64%	3017	1.21%	1.000	2911	0.965	1.17%	1.000	4461	1.479	1.14%	1.000	3258	1.080
	1.43%	4661	1.96%	1.000	5166	1.108	1.72%	1.000	4439	0.952	1.94%	1.000	4779	1.025
beasleyC3	31.53	97	31.66	1.004	97	1.000	31.47	0.998	83	**0.856**	31.56	1.001	83	**0.856**
	17.23	2	17.45	1.013	2	1.000	17.29	1.003	2	1.000	17.35	1.007	2	1.000
	31.84	120	31.85	1.000	120	1.000	46.75	*1.468*	424	*3.533*	47.20	*1.482*	453	*3.775*
binkar10_1	28.74	1910	29.29	1.019	1956	1.024	38.00	*1.322*	2899	*1.518*	31.34	*1.090*	2560	*1.340*
	36.65	2823	36.02	0.983	2595	**0.919**	29.45	**0.804**	2325	**0.824**	29.22	**0.797**	2246	**0.796**
	35.09	2658	36.61	1.043	3144	*1.183*	30.89	**0.880**	2376	**0.894**	28.71	**0.818**	2509	**0.944**
blp-ar98	0.28%	248630	0.33%	1.000	220479	0.887	0.34%	1.000	232824	0.936	0.27%	1.000	238231	0.958
	0.35%	255188	0.30%	1.000	201681	0.790	0.40%	1.000	213282	0.836	0.33%	1.000	207500	0.813
	0.27%	219266	0.22%	1.000	256441	1.170	0.25%	1.000	207438	0.946	0.32%	1.000	229423	1.046
blp-ic98	1.77%	328200	2.39%	1.000	298341	0.909	2.13%	1.000	268203	0.817	1.38%	1.000	304769	0.929
	1.79%	313664	1.39%	1.000	304794	0.972	1.54%	1.000	279606	0.891	2.41%	1.000	254061	0.810
	2.88%	311621	1.37%	1.000	283928	0.911	1.80%	1.000	284946	0.914	2.11%	1.000	278188	0.893
bnatt400	1013.96	5873	786.23	**0.775**	5563	**0.947**	1088.34	*1.073*	8660	*1.475*	970.91	0.958	6821	*1.161*
	839.92	7439	921.03	*1.097*	7122	0.957	977.85	*1.164*	5297	**0.712**	1105.02	*1.316*	6346	**0.853**
	779.62	5485	1071.66	*1.375*	8178	*1.491*	942.35	*1.209*	7395	*1.348*	745.15	0.956	5500	1.003
bnatt500	5290.44	37595	5371.93	1.015	37706	1.003	4207.70	**0.795**	31759	**0.845**	4368.17	**0.826**	29526	**0.785**
	6215.26	34819	6434.00	1.035	40497	*1.163*	6250.27	1.006	38236	*1.098*	6333.06	1.019	38962	*1.119*
	3370.42	24977	4014.00	*1.191*	27097	*1.085*	5003.35	*1.484*	29313	*1.174*	4996.90	*1.483*	29029	*1.162*
bppc4-08	1.92%	828046	1.92%	1.000	873421	1.055	1.92%	1.000	837029	1.011	1.92%	1.000	797503	0.963
	1.92%	814179	1.92%	1.000	844498	1.037	1.92%	1.000	898262	1.103	1.92%	1.000	938927	1.153
	6352.91	761343	1.92%	1.133	825334	1.084	1.92%	1.133	763383	1.003	1.92%	1.133	793397	1.042
brazil3	88.60%	8234	24.46%	1.000	7483	0.909	15.88%	1.000	8723	1.059	3360.46	**0.467**	2570	**0.312**
	25.81%	4781	0.00%	1.000	2280	0.477	4311.70	**0.599**	2243	**0.469**	4252.19	**0.591**	2347	**0.491**
	2900.92	1474	2444.40	**0.843**	1101	**0.747**	3063.82	*1.056*	2100	*1.425*	3785.08	*1.305*	3302	*2.240*
buildingenergy	0.13%	95	0.13%	1.000	94	0.989	0.13%	1.000	91	0.958	0.13%	1.000	96	1.011
	0.15%	97	0.15%	1.000	119	1.227	0.15%	1.000	101	1.041	0.15%	1.000	85	0.876
	0.13%	13	0.13%	1.000	12	0.923	0.13%	1.000	12	0.923	0.13%	1.000	12	0.923
cbs-cta	40.09	1	40.13	1.001	1	1.000	40.16	1.002	1	1.000	40.27	1.004	1	1.000
	314.25	31	311.39	0.991	31	1.000	313.28	0.997	31	1.000	314.10	1.000	31	1.000
	35.70	1	35.76	1.002	1	1.000	35.92	1.006	1	1.000	35.77	1.002	1	1.000
chromaticindex1024-7	33.33%	986	33.33%	1.000	985	0.999	33.33%	1.000	975	0.989	33.33%	1.000	964	0.978

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	33.33%	1627	33.33%	1.000	1627	1.000	33.33%	1.000	1176	0.723	33.33%	1.000	1171	0.720
	33.33%	718	0.00%	1.000	718	1.000	6472.23	**0.899**	772	*1.075*	6429.72	**0.893**	757	*1.054*
chromaticindex512-7	2004.52	707	2000.65	0.998	707	1.000	1154.13	**0.576**	365	**0.516**	1172.37	**0.585**	361	**0.511**
	33.33%	60358	0.00%	1.000	11439	0.190	3586.68	**0.498**	3461	**0.057**	3689.97	**0.512**	3133	**0.052**
	33.33%	23092	33.33%	1.000	27005	1.169	33.33%	1.000	20890	0.905	33.33%	1.000	40579	1.757
cmflsp50-24-8-8	3.64%	71420	3.98%	1.000	70708	0.990	3.39%	1.000	36887	0.516	3.98%	1.000	36090	0.505
	1.82%	57952	1.87%	1.000	66903	1.154	1.76%	1.000	44042	0.760	1.99%	1.000	85475	1.475
	∞	58514	2.86%	1.000	57828	0.988	∞	1.000	39783	0.680	4.86%	1.000	37790	0.646
co-100	48.51%	12176	1.74%	1.000	31192	2.562	2.54%	1.000	67083	5.509	1.74%	1.000	54008	4.436
	29.05%	13565	50.59%	1.000	11043	0.814	51.96%	1.000	12191	0.899	91.77%	1.000	7012	0.517
	94.07%	5635	49.46%	1.000	11744	2.084	44.78%	1.000	14277	2.534	3.18%	1.000	10565	1.875
cod105	48.29%	6746	47.86%	1.000	7069	1.048	47.90%	1.000	7067	1.048	47.57%	1.000	7261	1.076
	48.50%	6275	48.07%	1.000	6066	0.967	48.80%	1.000	6564	1.046	48.00%	1.000	6829	1.088
	47.79%	6894	48.07%	1.000	6526	0.947	48.38%	1.000	6573	0.953	48.07%	1.000	6601	0.957
comp07-2idx	1183.33%	3002	716.67%	1.000	3326	1.108	1116.67%	1.000	4030	1.342	966.67%	1.000	3996	1.331
	1316.67%	2052	2800.00%	1.000	1378	0.672	1183.33%	1.000	745	0.363	2800.00%	1.000	743	0.362
	1395.65%	1805	1700.00%	1.000	1623	0.899	1117.39%	1.000	3197	1.771	1716.67%	1.000	1449	0.803
comp21-2idx	220.19%	11966	208.58%	1.000	12927	1.080	198.83%	1.000	11442	0.956	247.43%	1.000	10931	0.914
	224.66%	7604	213.57%	1.000	8479	1.115	283.90%	1.000	10116	1.330	195.50%	1.000	9835	1.293
	230.83%	12201	237.62%	1.000	9505	0.779	239.90%	1.000	11111	0.911	248.72%	1.000	11711	0.960
cost266-UUE	3.89%	686321	0.00%	1.000	636741	0.928	6154.27	**0.855**	498762	**0.727**	4923.15	**0.684**	375684	**0.547**
	2.59%	585106	6.02%	1.000	636961	1.089	2.91%	1.000	31821	0.054	3728.83	**0.518**	294630	**0.504**
	2.90%	668583	0.00%	1.000	688748	1.030	7196.88	1.000	593150	**0.887**	4067.72	**0.565**	306702	**0.459**
cryptanalysiskb128n5obj14	∞	102	∞	1.000	101	0.990	∞	1.000	111	1.088	∞	1.000	110	1.078
	∞	47	∞	1.000	47	1.000	∞	1.000	56	1.191	∞	1.000	59	1.255
	∞	76	∞	1.000	76	1.000	∞	1.000	91	1.197	∞	1.000	90	1.184
cryptanalysiskb128n5obj16	∞	70	∞	1.000	70	1.000	∞	1.000	104	1.486	∞	1.000	104	1.486
	2820.78	37	2817.87	0.999	37	1.000	2794.70	0.991	37	1.000	2790.65	0.989	37	1.000
	∞	93	∞	1.000	93	1.000	∞	1.000	96	1.032	∞	1.000	97	1.043
csched007	10.27%	687997	0.00%	1.000	689922	1.003	2355.58	**0.327**	198606	**0.289**	2327.77	**0.323**	187288	**0.272**
	9.36%	802729	0.00%	1.000	700322	0.872	1855.85	**0.258**	142275	**0.177**	2613.95	**0.363**	220934	**0.275**
	1730.41	130969	0.00%	4.161	717094	5.475	4504.79	*2.603*	290068	*2.215*	3393.08	*1.961*	247755	*1.892*
csched008	2.34%	651889	1.16%	1.000	562768	0.863	1.17%	1.000	641728	0.984	2.81%	1.000	455870	0.699
	3.51%	694027	1.74%	1.000	430121	0.620	7.02%	1.000	711174	1.025	2.33%	1.000	694455	1.001

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	2.34%	467706	0.00%	1.000	716469	1.532	4674.39	**0.649**	404774	**0.865**	5772.95	**0.802**	546382	*1.168*
cvs16r128-89	21.37%	7991	24.18%	1.000	20714	2.592	20.46%	1.000	41034	5.135	23.28%	1.000	67980	8.507
	23.73%	25623	21.16%	1.000	35091	1.370	22.20%	1.000	41958	1.638	22.61%	1.000	34973	1.365
	24.35%	25468	25.04%	1.000	72611	2.851	21.83%	1.000	21851	0.858	23.01%	1.000	47219	1.854
dano3_3	146.25	12	152.34	1.042	10	**0.833**	161.59	*1.105*	10	**0.833**	143.70	0.983	10	**0.833**
	142.06	12	142.36	1.002	14	*1.167*	141.75	0.998	12	1.000	142.65	1.004	14	*1.167*
	124.70	17	124.58	0.999	17	1.000	124.81	1.001	17	1.000	124.56	0.999	17	1.000
dano3_5	567.06	220	618.61	*1.091*	176	**0.800**	634.53	*1.119*	276	*1.255*	635.04	*1.120*	276	*1.255*
	272.91	150	275.18	1.008	150	1.000	283.65	1.039	166	*1.107*	285.81	1.047	159	*1.060*
	287.49	140	287.54	1.000	140	1.000	286.08	0.995	140	1.000	285.94	0.995	140	1.000
decomp2	2.44	1	2.47	1.012	1	1.000	2.40	0.984	1	1.000	2.39	0.980	1	1.000
	2.42	1	2.51	1.037	1	1.000	2.47	1.021	1	1.000	2.42	1.000	1	1.000
	2.46	1	2.43	0.988	1	1.000	2.43	0.988	1	1.000	2.50	1.016	1	1.000
drayage-100-23	16.27	32	16.34	1.004	32	1.000	16.51	1.015	32	1.000	16.43	1.010	32	1.000
	19.84	48	19.61	0.988	48	1.000	19.63	0.989	48	1.000	19.52	0.984	48	1.000
	13.51	16	13.52	1.001	16	1.000	13.53	1.001	16	1.000	13.50	0.999	16	1.000
drayage-25-23	0.07%	517492	0.07%	1.000	492935	0.953	0.07%	1.000	747628	1.445	0.07%	1.000	720814	1.393
	0.07%	519847	0.07%	1.000	656944	1.264	0.07%	1.000	1043445	2.007	0.07%	1.000	790871	1.521
	6307.69	370729	5817.60	**0.922**	290807	**0.784**	0.00%	1.141	629308	1.697	6941.84	*1.101*	552534	*1.490*
dws008-01	96.91%	109911	52.83%	1.000	75442	0.686	214.11%	1.000	154301	1.404	44.84%	1.000	144766	1.317
	133.95%	98117	57.68%	1.000	81243	0.828	139.62%	1.000	168587	1.718	44.28%	1.000	157395	1.604
	144.33%	135628	54.29%	1.000	88474	0.652	184.89%	1.000	160318	1.182	52.63%	1.000	153108	1.129
eil33-2	45.91	715	92.42	*2.013*	595	**0.832**	67.05	*1.460*	561	**0.785**	81.20	*1.769*	343	**0.480**
	42.61	675	89.73	*2.106*	349	**0.517**	66.78	*1.567*	561	**0.831**	101.92	*2.392*	395	**0.585**
	37.22	571	87.43	*2.349*	517	**0.905**	55.12	*1.481*	615	*1.077*	105.72	*2.840*	541	**0.947**
eilA101-2	8.20%	18272	8.90%	1.000	11684	0.639	17.05%	1.000	11576	0.634	20.05%	1.000	11110	0.608
	13.98%	17070	13.47%	1.000	14309	0.838	13.28%	1.000	11712	0.686	13.20%	1.000	12688	0.743
	15.09%	12933	17.64%	1.000	13204	1.021	8.35%	1.000	12469	0.964	13.37%	1.000	13480	1.042
enlight_hard	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex10	493.68	1	495.08	1.003	1	1.000	497.29	1.007	1	1.000	493.80	1.000	1	1.000
	500.75	1	499.72	0.998	1	1.000	503.82	1.006	1	1.000	497.94	0.994	1	1.000
	575.26	1	577.33	1.004	1	1.000	580.75	1.010	1	1.000	581.12	1.010	1	1.000

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
ex9	28.09	1	28.15	1.002	1	1.000	28.06	0.999	1	1.000	27.98	0.996	1	1.000
	27.22	1	27.31	1.003	1	1.000	27.24	1.001	1	1.000	27.30	1.003	1	1.000
	27.70	1	27.65	0.998	1	1.000	27.58	0.996	1	1.000	27.02	0.975	1	1.000
exp-1-500-5-5	2.26	1	2.25	0.996	1	1.000	2.31	1.022	1	1.000	2.28	1.009	1	1.000
	2.21	1	2.22	1.005	1	1.000	2.22	1.005	1	1.000	2.22	1.005	1	1.000
	2.19	1	2.23	1.018	1	1.000	2.23	1.018	1	1.000	2.21	1.009	1	1.000
fast0507	263.98	1041	260.94	0.988	1045	1.004	305.72	*1.158*	1377	*1.323*	322.23	*1.221*	1284	*1.233*
	180.54	779	265.86	*1.473*	1032	*1.325*	180.00	0.997	789	1.013	280.17	*1.552*	1223	*1.570*
	160.11	709	165.64	1.035	725	1.023	245.54	*1.534*	1054	*1.487*	365.44	*2.282*	1711	*2.413*
fastxgemm-n2r6s0t2	4526.87	1024921	4436.56	0.980	1014208	0.990	4774.24	*1.055*	1136260	*1.109*	4702.82	1.039	1118937	*1.092*
	3208.37	771817	2657.63	**0.828**	653762	**0.847**	2579.71	**0.804**	609753	**0.790**	4017.11	*1.252*	1012967	*1.312*
	3676.54	839760	2060.35	**0.560**	492173	**0.586**	4374.81	*1.190*	1031868	*1.229*	3129.08	**0.851**	769500	**0.916**
fhnw-binpack4-48	∞	4061521	∞	1.000	4056706	0.999	∞	1.000	4041612	0.995	∞	1.000	4040499	0.995
	∞	3509133	∞	1.000	3529464	1.006	∞	1.000	3536197	1.008	∞	1.000	3525851	1.005
	∞	3421178	∞	1.000	3422722	1.000	∞	1.000	3412172	0.997	∞	1.000	3413924	0.998
fhnw-binpack4-4	∞	14301362	∞	1.000	14587388	1.020	∞	1.000	14867910	1.040	∞	1.000	14733968	1.030
	∞	13031703	∞	1.000	13154203	1.009	∞	1.000	13767692	1.056	∞	1.000	13981261	1.073
	∞	12591238	∞	1.000	12342714	0.980	∞	1.000	13360396	1.061	∞	1.000	11607995	0.922
fiball	1342.69	20372	394.03	**0.293**	4360	**0.214**	600.45	**0.447**	5853	**0.287**	465.55	**0.347**	4111	**0.202**
	2372.29	38260	3821.84	*1.611*	70292	*1.837*	425.63	**0.179**	3216	**0.084**	447.14	**0.188**	3521	**0.092**
	2260.11	40321	1464.73	**0.648**	22881	**0.567**	870.35	**0.385**	10338	**0.256**	499.03	**0.221**	5672	**0.141**
gen-ip002	1637.26	6690190	1462.75	**0.893**	6425170	0.960	1413.15	**0.863**	5796348	**0.866**	1315.68	**0.804**	5856334	**0.875**
	1363.72	5677895	1205.12	**0.884**	5345710	**0.941**	1385.70	1.016	5542663	0.976	1295.56	0.950	5478569	0.965
	1256.64	5282471	1220.88	0.972	5404068	1.023	1308.21	1.041	5647374	*1.069*	1271.92	1.012	5583912	*1.057*
gen-ip054	2987.96	14800834	2362.69	**0.791**	12067757	**0.815**	3157.12	*1.057*	15026943	1.015	3047.64	1.020	15245360	1.030
	2406.71	11923977	2361.66	0.981	12180453	1.022	2349.71	0.976	11384216	0.955	2530.93	*1.052*	12476019	1.046
	3625.10	17356622	3148.80	**0.869**	15904430	**0.916**	4437.62	*1.224*	21063822	*1.214*	3381.24	**0.933**	16438070	**0.947**
germanrr	1.90%	2307	1.99%	1.000	3377	1.464	2.92%	1.000	2451	1.062	1.46%	1.000	3418	1.482
	0.91%	6855	2.24%	1.000	3719	0.543	2.13%	1.000	4636	0.676	2.11%	1.000	2851	0.416
	2.21%	4055	1.72%	1.000	2764	0.682	2.06%	1.000	5055	1.247	1.94%	1.000	3559	0.878
gfd-schedulen180f7d50m30k18	∞	4	∞	1.000	4	1.000	∞	1.000	4	1.000	∞	1.000	4	1.000
	∞	8	∞	1.000	8	1.000	∞	1.000	8	1.000	∞	1.000	8	1.000
	∞	10	∞	1.000	10	1.000	∞	1.000	10	1.000	∞	1.000	10	1.000
glass-sc	2610.23	240737	2615.32	1.002	240737	1.000	2660.27	1.019	241365	1.003	2655.26	1.017	241329	1.002

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	3099.62	287279	3100.56	1.000	287279	1.000	3217.14	1.038	289206	1.007	3214.67	1.037	289206	1.007
	2829.27	259617	2834.65	1.002	259617	1.000	2831.50	1.001	251112	0.967	2819.06	0.996	251112	0.967
glass4	3361.67	3222725	3730.47	*1.110*	2847284	**0.884**	4404.19	*1.310*	3566262	*1.107*	4008.75	*1.192*	2705421	**0.839**
	3696.91	2574365	2755.59	**0.745**	1956253	**0.760**	1461.74	**0.395**	1253927	**0.487**	2392.84	**0.647**	1888717	**0.734**
	65.45%	3880956	2488.84	**0.346**	1896614	**0.489**	1664.10	**0.231**	1290615	**0.333**	2212.84	**0.307**	1599046	**0.412**
gmu-35-40	0.04%	2403537	0.03%	1.000	1875561	0.780	0.05%	1.000	1621723	0.675	0.05%	1.000	2051936	0.854
	0.02%	2737264	0.01%	1.000	2330157	0.851	0.03%	1.000	4847633	1.771	0.03%	1.000	2099939	0.767
	0.02%	2488628	0.02%	1.000	1935051	0.778	0.03%	1.000	2229459	0.896	0.03%	1.000	1381092	0.555
gmu-35-50	0.04%	1407863	0.04%	1.000	1082035	0.769	0.03%	1.000	2253407	1.601	0.02%	1.000	1317781	0.936
	0.05%	1367835	0.04%	1.000	1400949	1.024	0.06%	1.000	1245342	0.910	0.03%	1.000	1247342	0.912
	0.02%	1661966	0.09%	1.000	1327315	0.799	0.03%	1.000	1581744	0.952	0.04%	1.000	1016723	0.612
graph20-20-1rand	165.99%	8594	166.96%	1.000	14229	1.656	163.33%	1.000	15598	1.815	163.73%	1.000	6171	0.718
	164.20%	8533	165.69%	1.000	7958	0.933	157.48%	1.000	8521	0.999	165.38%	1.000	8277	0.970
	161.28%	8662	157.72%	1.000	5357	0.618	162.94%	1.000	12195	1.408	172.66%	1.000	7513	0.867
graphdraw-domain	1054.45	1819134	1079.90	1.024	1914872	*1.053*	1495.01	*1.418*	2660827	*1.463*	1010.47	0.958	1823083	1.002
	1592.76	2718947	1631.15	1.024	2887685	*1.062*	1201.21	**0.754**	2031193	**0.747**	1122.85	**0.705**	1941578	**0.714**
	2174.25	4328282	2647.33	*1.218*	5129739	*1.185*	1407.78	**0.647**	2460247	**0.568**	1664.67	**0.766**	2907888	**0.672**
h80x6320d	72.87	4	72.75	0.998	4	1.000	69.89	0.959	4	1.000	69.54	0.954	4	1.000
	84.11	10	86.16	1.024	6	**0.600**	86.18	1.025	6	**0.600**	86.17	1.024	10	1.000
	82.69	5	82.28	0.995	5	1.000	84.54	1.022	5	1.000	86.62	1.048	5	1.000
highschool1-aigio	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
hypothyroid-k1	19.88	1	19.81	0.996	1	1.000	19.80	0.996	1	1.000	20.04	1.008	1	1.000
	20.03	1	20.18	1.007	1	1.000	20.09	1.003	1	1.000	19.99	0.998	1	1.000
	20.05	1	20.09	1.002	1	1.000	20.09	1.002	1	1.000	20.16	1.005	1	1.000
ic97_potential	0.78%	7017703	0.88%	1.000	7145954	1.018	1.00%	1.000	7395272	1.054	0.84%	1.000	7214792	1.028
	0.69%	5804129	0.63%	1.000	5798606	0.999	0.68%	1.000	5981239	1.031	0.75%	1.000	6107856	1.052
	0.83%	7802905	0.81%	1.000	7417661	0.951	0.87%	1.000	7028351	0.901	0.86%	1.000	7579116	0.971
icir97_tension	0.14%	3248344	0.08%	1.000	3177252	0.978	0.15%	1.000	3153191	0.971	0.07%	1.000	3185773	0.981
	0.19%	3075583	0.11%	1.000	3357421	1.092	0.19%	1.000	3293768	1.071	0.05%	1.000	2776552	0.903
	0.15%	2917582	0.14%	1.000	2580824	0.885	0.13%	1.000	3126098	1.071	0.08%	1.000	2729235	0.935
irish-electricity	∞	93	∞	1.000	93	1.000	∞	1.000	93	1.000	∞	1.000	93	1.000
	∞	1301	26.89%	1.000	1289	0.991	∞	1.000	1551	1.192	18.43%	1.000	1317	1.012

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	24.70%	1069	∞	1.000	1069	1.000	24.68%	1.000	1333	1.247	∞	1.000	1333	1.247
irp	11.12	5	11.67	1.049	5	1.000	11.54	1.038	4	**0.800**	12.51	*1.125*	6	*1.200*
	11.24	4	11.44	1.018	4	1.000	11.98	*1.066*	5	*1.250*	12.05	*1.072*	4	1.000
	10.87	4	11.70	*1.076*	5	*1.250*	11.75	*1.081*	5	*1.250*	12.58	*1.157*	5	*1.250*
istanbul-no-cutoff	237.19	303	230.84	0.973	325	*1.073*	151.26	**0.638**	341	*1.125*	154.02	**0.649**	347	*1.145*
	162.70	243	168.76	1.037	251	1.033	164.91	1.014	269	*1.107*	166.34	1.022	245	1.008
	201.52	252	210.97	1.047	318	*1.262*	291.44	*1.446*	481	*1.909*	285.14	*1.415*	475	*1.885*
k1mushroom	1903.50	8	1925.59	1.012	8	1.000	1888.10	0.992	7	**0.875**	1897.56	0.997	7	**0.875**
	1542.11	12	1552.17	1.007	12	1.000	1577.86	1.023	11	**0.917**	1583.93	1.027	11	**0.917**
	1311.58	3	1337.63	1.020	3	1.000	1300.61	0.992	3	1.000	1321.29	1.007	3	1.000
lectsched-5-obj	86.67%	470059	153.33%	1.000	176467	0.375	73.33%	1.000	146777	0.312	166.67%	1.000	148725	0.316
	166.67%	94376	146.67%	1.000	123120	1.305	120.00%	1.000	155448	1.647	120.00%	1.000	130812	1.386
	186.67%	135345	153.33%	1.000	129017	0.953	133.33%	1.000	160845	1.188	126.67%	1.000	64923	0.480
leo1	4.94%	91033	5.72%	1.000	65473	0.719	7.38%	1.000	84658	0.930	6.11%	1.000	80819	0.888
	5.18%	63501	6.06%	1.000	54706	0.861	6.74%	1.000	56994	0.898	7.14%	1.000	34905	0.550
	3.77%	124951	6.66%	1.000	72699	0.582	6.71%	1.000	78110	0.625	7.53%	1.000	45969	0.368
leo2	∞	98306	∞	1.000	92645	0.942	∞	1.000	98792	1.005	∞	1.000	101616	1.034
	∞	117321	∞	1.000	112056	0.955	∞	1.000	116130	0.990	∞	1.000	110967	0.946
	∞	119104	∞	1.000	108386	0.910	∞	1.000	111129	0.933	∞	1.000	146706	1.232
lotsize	0.65%	30540	0.54%	1.000	32475	1.063	0.57%	1.000	25529	0.836	0.67%	1.000	16786	0.550
	0.89%	19887	0.81%	1.000	18915	0.951	0.68%	1.000	17210	0.865	0.88%	1.000	20493	1.030
	0.55%	19259	0.55%	1.000	20397	1.059	0.53%	1.000	17047	0.885	0.70%	1.000	17911	0.930
mad	∞	19866742	∞	1.000	21601059	1.087	∞	1.000	17130554	0.862	∞	1.000	8295624	0.418
	∞	19368363	∞	1.000	23790571	1.228	∞	1.000	22548896	1.164	∞	1.000	14934806	0.771
	∞	25228092	∞	1.000	19697850	0.781	∞	1.000	10115378	0.401	∞	1.000	15381075	0.610
map10	1074.59	1672	1057.50	0.984	1595	0.954	1051.44	0.978	1494	**0.894**	1006.71	**0.937**	1637	0.979
	670.14	768	633.71	**0.946**	724	**0.943**	674.45	1.006	768	1.000	633.84	**0.946**	724	**0.943**
	797.43	961	788.49	0.989	965	1.004	821.19	1.030	955	0.994	792.96	0.994	965	1.004
map16715-04	1928.50	1780	1917.79	0.994	1782	1.001	2149.49	*1.115*	1961	*1.102*	2158.43	*1.119*	1933	*1.086*
	2201.33	2317	2181.44	0.991	2323	1.003	2407.24	*1.094*	2279	0.984	2335.51	*1.061*	2173	**0.938**
	1987.28	1903	1978.40	0.996	1989	1.045	2052.84	1.033	1982	1.042	2160.04	*1.087*	1990	1.046
markshare2	∞	5801369	∞	1.000	7092947	1.223	∞	1.000	5339206	0.920	∞	1.000	5827069	1.004
	∞	5912079	∞	1.000	7825289	1.324	∞	1.000	6744463	1.141	∞	1.000	5581862	0.944
	∞	5830446	∞	1.000	8087128	1.387	∞	1.000	5448970	0.935	∞	1.000	5052479	0.867

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
markshare_4_0	236.70	2086134	57.79	**0.244**	506673	**0.243**	290.41	*1.227*	2571032	*1.232*	72.47	**0.306**	612396	**0.294**
	293.15	2638602	58.16	**0.198**	506440	**0.192**	303.00	1.034	2661583	1.009	70.48	**0.240**	589762	**0.224**
	337.30	3027177	61.29	**0.182**	535874	**0.177**	254.91	**0.756**	2235991	**0.739**	85.88	**0.255**	719508	**0.238**
mas74	1488.86	4599675	1523.56	1.023	4437792	0.965	1660.70	*1.115*	5061685	*1.100*	1680.79	*1.129*	4932223	*1.072*
	2043.77	8010454	2245.73	*1.099*	8397860	1.048	2270.66	*1.111*	8044752	1.004	2282.09	*1.117*	7992914	0.998
	1193.28	3776851	1171.70	0.982	3539157	**0.937**	1295.72	*1.086*	3949864	1.046	1563.59	*1.310*	4674399	*1.238*
mas76	143.17	464809	143.71	1.004	451946	0.972	135.70	**0.948**	423620	**0.911**	136.88	0.956	406104	**0.874**
	128.54	451893	137.95	*1.073*	445456	0.986	167.25	*1.301*	530482	*1.174*	168.46	*1.311*	525538	*1.163*
	145.73	466086	146.06	1.002	466086	1.000	143.18	0.983	448267	0.962	152.65	1.047	450422	0.966
mc11	77.69	1115	73.77	**0.950**	1097	0.984	169.88	*2.187*	7587	*6.804*	149.40	*1.923*	6484	*5.815*
	125.34	3364	210.52	*1.680*	9069	*2.696*	101.25	**0.808**	2695	**0.801**	80.39	**0.641**	1411	**0.419**
	304.49	15636	210.21	**0.690**	10462	**0.669**	93.14	**0.306**	2184	**0.140**	106.11	**0.348**	3386	**0.217**
mcsched	326.38	16119	329.92	1.011	15321	0.950	356.03	*1.091*	15011	**0.931**	318.21	0.975	11378	**0.706**
	250.87	9466	251.72	1.003	9346	0.987	234.36	**0.934**	9846	1.040	235.33	**0.938**	9846	1.040
	300.36	10393	302.05	1.006	10393	1.000	296.46	0.987	10929	*1.052*	306.32	1.020	12017	*1.156*
mik-250-20-75-4	37.33	18256	37.57	1.006	18256	1.000	52.24	*1.399*	23893	*1.309*	52.78	*1.414*	23893	*1.309*
	33.56	11362	33.97	1.012	11362	1.000	43.42	*1.294*	15175	*1.336*	43.96	*1.310*	15175	*1.336*
	43.44	19440	44.17	1.017	19440	1.000	51.68	*1.190*	20733	*1.067*	52.36	*1.205*	20733	*1.067*
milo-v12-6-r2-40-1	11.69%	316375	11.75%	1.000	267871	0.847	12.13%	1.000	182031	0.575	9.47%	1.000	189681	0.600
	14.53%	625060	7.15%	1.000	651134	1.042	14.88%	1.000	281347	0.450	8.96%	1.000	323326	0.517
	15.59%	417505	8.00%	1.000	352982	0.845	7.72%	1.000	253424	0.607	11.33%	1.000	417232	0.999
momentum1	6.26%	220224	18.92%	1.000	102188	0.464	17.09%	1.000	84524	0.384	24.76%	1.000	94037	0.427
	10.07%	168760	6.07%	1.000	160967	0.954	8.42%	1.000	139445	0.826	7.36%	1.000	91471	0.542
	22.05%	124661	15.71%	1.000	83468	0.670	12.48%	1.000	118833	0.953	6.53%	1.000	188055	1.509
mushroom-best	601.92	38299	686.16	*1.140*	45244	*1.181*	914.59	*1.519*	49975	*1.305*	579.50	0.963	27393	**0.715**
	149.25%	95652	168.90%	1.000	102468	1.071	152.86%	1.000	96841	1.012	134.09%	1.000	94624	0.989
	133.13%	88725	99.98%	1.000	87509	0.986	141.07%	1.000	92063	1.038	121.97%	1.000	98893	1.115
mzzv11	266.96	1684	288.00	*1.079*	1419	**0.843**	212.06	**0.794**	484	**0.287**	210.71	**0.789**	484	**0.287**
	272.18	942	298.87	*1.098*	998	*1.059*	339.71	*1.248*	1705	*1.810*	263.08	0.967	987	1.048
	176.40	614	175.33	0.994	614	1.000	196.13	*1.112*	616	1.003	195.89	*1.110*	616	1.003
mzzv42z	166.49	369	166.64	1.001	369	1.000	171.22	1.028	366	0.992	175.26	*1.053*	415	*1.125*
	239.97	423	238.81	0.995	423	1.000	245.79	1.024	712	*1.683*	246.00	1.025	712	*1.683*
	343.90	841	323.81	**0.942**	748	**0.889**	267.18	**0.777**	659	**0.784**	306.34	**0.891**	719	**0.855**
n2seq36q	469.42	2725	532.44	*1.134*	2724	1.000	1725.67	*3.676*	8925	*3.275*	936.81	*1.996*	5438	*1.996*

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1728.61	5439	462.25	**0.267**	1787	**0.329**	600.84	**0.348**	2918	**0.536**	1061.28	**0.614**	4712	**0.866**
	1136.74	3368	944.89	**0.831**	5173	*1.536*	806.68	**0.710**	2231	**0.662**	1170.79	1.030	4632	*1.375*
n3div36	2.36%	274686	2.83%	1.000	234844	0.855	2.80%	1.000	219980	0.801	2.59%	1.000	213866	0.779
	2.28%	258749	2.79%	1.000	237068	0.916	2.42%	1.000	220414	0.852	2.86%	1.000	207136	0.801
	2.32%	261492	2.65%	1.000	234539	0.897	2.42%	1.000	224994	0.860	2.69%	1.000	202891	0.776
n5-3	28.07	1142	28.62	1.020	1068	**0.935**	29.63	*1.056*	1184	1.037	26.40	**0.941**	926	**0.811**
	27.04	893	28.36	1.049	937	1.049	26.99	0.998	1008	*1.129*	27.79	1.028	971	*1.087*
	28.03	1195	27.38	0.977	1158	0.969	25.54	**0.911**	1047	**0.876**	27.09	0.966	1087	**0.910**
neos-1122047	10.16	1	9.74	0.959	1	1.000	9.89	0.973	1	1.000	9.92	0.976	1	1.000
	9.84	1	9.81	0.997	1	1.000	9.58	0.974	1	1.000	9.76	0.992	1	1.000
	9.89	1	9.77	0.988	1	1.000	10.01	1.012	1	1.000	9.70	0.981	1	1.000
neos-1171448	84.76	85	87.39	1.031	85	1.000	7.14	**0.084**	1	**0.012**	58.11	**0.686**	101	*1.188*
	6.21	1	83.56	*13.456*	138	*138.000*	4806.35	*773.969*	373	*373.000*	5.16	**0.831**	1	1.000
	2744.66	201	2743.51	1.000	201	1.000	51.43	**0.019**	86	**0.428**	51.55	**0.019**	86	**0.428**
neos-1171737	1.39%	4394	1.30%	1.000	4667	1.062	1.56%	1.000	4476	1.019	1.04%	1.000	3912	0.890
	1.56%	4065	1.04%	1.000	4331	1.065	1.04%	1.000	3545	0.872	1.56%	1.000	4009	0.986
	1.56%	3977	1.56%	1.000	4040	1.016	2.09%	1.000	8518	2.142	1.30%	1.000	11719	2.947
neos-1354092	∞	133	∞	1.000	283	2.128	∞	1.000	613	4.609	∞	1.000	613	4.609
	∞	88	∞	1.000	846	9.614	∞	1.000	821	9.330	∞	1.000	820	9.318
	∞	123	∞	1.000	641	5.211	∞	1.000	639	5.195	∞	1.000	639	5.195
neos-1445765	43.63	129	43.70	1.002	129	1.000	43.57	0.999	133	1.031	43.72	1.002	133	1.031
	44.45	161	44.17	0.994	145	**0.901**	45.18	1.016	185	*1.149*	44.19	0.994	141	**0.876**
	43.42	115	44.77	1.031	115	1.000	44.28	1.020	125	*1.087*	44.74	1.030	125	*1.087*
neos-1456979	8.35%	67269	7.30%	1.000	278148	4.135	4.89%	1.000	37787	0.562	7.49%	1.000	39961	0.594
	7.90%	50358	7.72%	1.000	38121	0.757	8.47%	1.000	42543	0.845	6.84%	1.000	38750	0.769
	6.37%	76767	7.21%	1.000	48821	0.636	7.76%	1.000	33278	0.433	7.29%	1.000	31540	0.411
neos-1582420	23.82	15	24.12	1.013	15	1.000	21.77	**0.914**	18	*1.200*	21.85	**0.917**	18	*1.200*
	10.87	9	10.91	1.004	9	1.000	10.94	1.006	9	1.000	10.92	1.005	9	1.000
	77.35	3052	85.73	*1.108*	3522	*1.154*	58.44	**0.756**	1411	**0.462**	55.49	**0.717**	1381	**0.452**
neos-2075418-temuka	7089.82	1	7125.91	1.005	1	1.000	7032.92	0.992	1	1.000	7024.05	0.991	1	1.000
	4584.98	1	4723.80	1.030	1	1.000	4548.21	0.992	1	1.000	4517.94	0.985	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
neos-2657525-crna	∞	3299274	∞	1.000	6291727	1.907	∞	1.000	3385022	1.026	∞	1.000	3064132	0.929
	∞	5517891	∞	1.000	2093469	0.379	∞	1.000	3373221	0.611	∞	1.000	3681104	0.667

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	1132061	∞	1.000	2988312	2.640	∞	1.000	1912631	1.690	∞	1.000	2122332	1.875
neos-2746589-doon	0.11%	162360	0.59%	1.000	55166	0.340	0.76%	1.000	51130	0.315	0.46%	1.000	55681	0.343
	0.78%	63981	0.47%	1.000	21915	0.343	0.71%	1.000	42771	0.668	0.73%	1.000	30280	0.473
	1.03%	37418	0.15%	1.000	140498	3.755	0.11%	1.000	104934	2.804	0.11%	1.000	182349	4.873
neos-2978193-inde	0.50%	565366	0.50%	1.000	532689	0.942	0.50%	1.000	573871	1.015	0.50%	1.000	549249	0.971
	0.13%	543501	0.13%	1.000	490690	0.903	0.13%	1.000	607287	1.117	0.13%	1.000	573707	1.056
	0.50%	659412	0.50%	1.000	606931	0.920	0.50%	1.000	576992	0.875	0.50%	1.000	548119	0.831
neos-2987310-joes	17.53	1	17.71	1.010	1	1.000	17.54	1.001	1	1.000	17.49	0.998	1	1.000
	15.24	1	15.49	1.016	1	1.000	15.26	1.001	1	1.000	15.31	1.005	1	1.000
	13.84	1	13.58	0.981	1	1.000	14.08	1.017	1	1.000	13.67	0.988	1	1.000
neos-3004026-krka	53.53	2711	53.11	0.992	2711	1.000	52.94	0.989	2711	1.000	53.06	0.991	2711	1.000
	62.04	3485	62.32	1.005	3485	1.000	62.38	1.005	3485	1.000	62.47	1.007	3485	1.000
	46.94	1764	46.39	0.988	1764	1.000	46.81	0.997	1764	1.000	46.28	0.986	1764	1.000
neos-3024952-loue	4345.61	243005	0.00%	1.657	716114	2.947	4622.43	*1.064*	460419	*1.895*	4646.86	*1.069*	383076	*1.576*
	2843.41	232504	0.00%	2.532	735092	3.162	6811.25	*2.395*	146416	**0.630**	0.07%	2.532	688312	2.960
	0.03%	1222088	0.00%	1.000	1328073	1.087	2895.54	**0.402**	284214	**0.233**	0.04%	1.000	1114650	0.912
neos-3046615-murg	164.03%	7383815	169.34%	1.000	7294799	0.988	167.45%	1.000	7650082	1.036	169.81%	1.000	6971706	0.944
	158.67%	6758319	160.91%	1.000	6970702	1.031	165.78%	1.000	7162151	1.060	166.11%	1.000	6364063	0.942
	170.27%	6907435	171.19%	1.000	7347532	1.064	158.38%	1.000	6656911	0.964	163.66%	1.000	7613539	1.102
neos-3083819-nubu	11.13	2169	10.44	**0.938**	1436	**0.662**	8.66	**0.778**	1152	**0.531**	12.72	*1.143*	2020	**0.931**
	13.56	2410	14.64	*1.080*	2757	*1.144*	13.71	1.011	2810	*1.166*	12.37	**0.912**	1578	**0.655**
	8.55	1264	12.94	*1.513*	1621	*1.282*	11.86	*1.387*	1572	*1.244*	20.79	*2.432*	3812	*3.016*
neos-3216931-puriri	92.16%	5249	4697.10	**0.652**	6620	*1.261*	0.00%	1.000	6141	1.170	116.41%	1.000	5546	1.057
	102.21%	5127	151.91%	1.000	5234	1.021	105.05%	1.000	7914	1.544	5.50%	1.000	9705	1.893
	62.44%	10170	98.45%	1.000	8686	0.854	54.80%	1.000	4036	0.397	147.13%	1.000	4790	0.471
neos-3381206-awhea	1.20	1	1.20	1.000	1	1.000	1.18	0.983	1	1.000	1.18	0.983	1	1.000
	1.19	1	1.23	1.034	1	1.000	1.22	1.025	1	1.000	1.21	1.017	1	1.000
	1.23	1	1.23	1.000	1	1.000	1.22	0.992	1	1.000	1.20	0.976	1	1.000
neos-3402294-bobin	451.09	1373	1382.68	*3.065*	8164	*5.946*	0.00%	15.961	126719	92.294	4386.37	*9.724*	40294	*29.347*
	4298.33	85397	2561.11	**0.596**	17828	**0.209**	729.52	**0.170**	3567	**0.042**	618.95	**0.144**	3428	**0.040**
	6958.94	116536	1316.19	**0.189**	8496	**0.073**	2067.79	**0.297**	32941	**0.283**	1620.92	**0.233**	9242	**0.079**
neos-3402454-bohle	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
neos-3555904-turama	18.01%	226	18.01%	1.000	1239	5.482	18.01%	1.000	242	1.071	18.01%	1.000	145	0.642
	18.01%	1441	∞	1.000	1482	1.028	18.01%	1.000	18	0.012	∞	1.000	18	0.012
	18.01%	933	18.01%	1.000	1999	2.143	18.01%	1.000	1451	1.555	18.01%	1.000	16797	18.003
neos-3627168-kasai	0.15%	4132691	0.20%	1.000	4565939	1.105	0.19%	1.000	5323290	1.288	0.15%	1.000	4555684	1.102
	0.18%	4202463	0.05%	1.000	4997144	1.189	0.30%	1.000	4481459	1.066	0.09%	1.000	4132791	0.983
	0.13%	5322396	0.16%	1.000	5017213	0.943	0.09%	1.000	5055583	0.950	0.27%	1.000	5147129	0.967
neos-3656078-kumeu	∞	121	∞	1.000	119	0.983	∞	1.000	32	0.264	∞	1.000	32	0.264
	∞	55	∞	1.000	66	1.200	∞	1.000	78	1.418	∞	1.000	82	1.491
	∞	182	∞	1.000	145	0.797	∞	1.000	91	0.500	∞	1.000	122	0.670
neos-3754480-nidda	∞	20491511	∞	1.000	19451714	0.949	∞	1.000	19768212	0.965	∞	1.000	20000763	0.976
	∞	18761545	∞	1.000	20139473	1.073	∞	1.000	18945457	1.010	∞	1.000	18439214	0.983
	∞	18808301	∞	1.000	18759033	0.997	∞	1.000	19667861	1.046	∞	1.000	19108471	1.016
neos-3988577-wolgan	∞	782	∞	1.000	759	0.971	∞	1.000	309	0.395	∞	1.000	312	0.399
	∞	924	∞	1.000	724	0.784	∞	1.000	179	0.194	∞	1.000	179	0.194
	∞	207	∞	1.000	207	1.000	∞	1.000	717	3.464	∞	1.000	439	2.121
neos-4300652-rahue	469.51%	1823	431.97%	1.000	1821	0.999	469.51%	1.000	1361	0.747	431.97%	1.000	1365	0.749
	480.09%	1682	809.48%	1.000	1689	1.004	480.09%	1.000	1231	0.732	809.48%	1.000	1213	0.721
	447.02%	1843	316.83%	1.000	1814	0.984	450.30%	1.000	2129	1.155	316.83%	1.000	2127	1.154
neos-4338804-snowy	1.80%	5559491	2.07%	1.000	5279174	0.950	2.07%	1.000	4845423	0.872	1.66%	1.000	4875741	0.877
	1.66%	6018460	1.03%	1.000	6323179	1.051	0.82%	1.000	6863695	1.140	0.82%	1.000	6738902	1.120
	2.07%	4759127	1.80%	1.000	5540955	1.164	1.66%	1.000	5028993	1.057	1.66%	1.000	5067404	1.065
neos-4387871-tavua	14.63%	114709	14.99%	1.000	111191	0.969	12.49%	1.000	110732	0.965	11.39%	1.000	118375	1.032
	11.12%	123324	12.85%	1.000	114595	0.929	13.44%	1.000	124981	1.013	14.13%	1.000	116171	0.942
	13.54%	89794	19.40%	1.000	100558	1.120	15.31%	1.000	136923	1.525	18.66%	1.000	96695	1.077
neos-4413714-turia	298.75	3	300.59	1.006	2	**0.667**	296.43	0.992	2	**0.667**	299.23	1.002	2	**0.667**
	399.68	3	402.66	1.007	2	**0.667**	404.13	1.011	2	**0.667**	404.80	1.013	2	**0.667**
	278.42	3	279.01	1.002	2	**0.667**	276.25	0.992	2	**0.667**	277.10	0.995	2	**0.667**
neos-4532248-waihi	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
neos-4647030-tutaki	0.01%	24622	0.01%	1.000	24883	1.011	0.01%	1.000	24546	0.997	0.01%	1.000	24413	0.992
	0.01%	23131	0.01%	1.000	22822	0.987	0.01%	1.000	23140	1.000	0.01%	1.000	22893	0.990
	0.01%	27029	0.01%	1.000	27449	1.016	0.01%	1.000	26762	0.990	0.01%	1.000	27292	1.010
neos-4722843-widden	1477.17	5194	1733.78	*1.174*	7617	*1.466*	1909.19	*1.292*	7770	*1.496*	2651.33	*1.795*	11357	*2.187*

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1122.56	3329	999.02	**0.890**	2137	**0.642**	2457.98	*2.190*	14149	*4.250*	1033.65	**0.921**	3376	1.014
	1228.51	6749	1837.93	*1.496*	9866	*1.462*	2060.45	*1.677*	13340	*1.977*	1714.52	*1.396*	7919	*1.173*
neos-4738912-atrato	3125.62	373759	1868.51	**0.598**	202053	**0.541**	1452.46	**0.465**	161598	**0.432**	813.40	**0.260**	61981	**0.166**
	6412.46	647654	7161.92	*1.117*	720001	*1.112*	2835.53	**0.442**	283058	**0.437**	3808.90	**0.594**	324992	**0.502**
	416.64	42417	1097.85	*2.635*	125625	*2.962*	928.76	*2.229*	99490	*2.346*	914.39	*2.195*	95736	*2.257*
neos-4763324-toguru	45.60%	13821	47.64%	1.000	9891	0.716	45.98%	1.000	13955	1.010	46.04%	1.000	8436	0.610
	43.56%	11665	44.03%	1.000	18186	1.559	40.72%	1.000	15972	1.369	45.08%	1.000	14962	1.283
	40.43%	18283	43.24%	1.000	3715	0.203	47.52%	1.000	14763	0.807	48.94%	1.000	7145	0.391
neos-4954672-berkel	8.37%	919377	7.86%	1.000	940482	1.023	8.37%	1.000	899492	0.978	8.48%	1.000	1019990	1.109
	9.27%	793996	9.38%	1.000	726920	0.916	9.05%	1.000	745631	0.939	8.71%	1.000	819107	1.032
	8.46%	876968	8.19%	1.000	772111	0.880	7.47%	1.000	844559	0.963	8.00%	1.000	891993	1.017
neos-5049753-cuanza	∞	52	∞	1.000	52	1.000	∞	1.000	52	1.000	∞	1.000	52	1.000
	15.39%	14	15.39%	1.000	14	1.000	15.39%	1.000	14	1.000	15.39%	1.000	14	1.000
	15.20%	12	15.20%	1.000	12	1.000	15.20%	1.000	12	1.000	15.20%	1.000	12	1.000
neos-5052403-cygnet	1.56%	155	1.60%	1.000	158	1.019	1.56%	1.000	113	0.729	1.60%	1.000	113	0.729
	1.38%	1	1.38%	1.000	1	1.000	1.38%	1.000	1	1.000	1.38%	1.000	1	1.000
	1.25%	53	1.19%	1.000	53	1.000	1.25%	1.000	63	1.189	1.19%	1.000	63	1.189
neos-5093327-huahum	9.13%	57648	9.26%	1.000	49858	0.865	10.85%	1.000	56108	0.973	10.32%	1.000	49854	0.865
	8.08%	57974	13.69%	1.000	55253	0.953	8.42%	1.000	50716	0.875	10.43%	1.000	52521	0.906
	10.14%	50556	9.60%	1.000	48637	0.962	10.07%	1.000	53217	1.053	12.17%	1.000	48532	0.960
neos-5104907-jarama	∞	7	∞	1.000	7	1.000	∞	1.000	8	1.143	∞	1.000	8	1.143
	∞	10	∞	1.000	10	1.000	∞	1.000	9	0.900	∞	1.000	9	0.900
	∞	4	∞	1.000	4	1.000	∞	1.000	4	1.000	∞	1.000	4	1.000
neos-5107597-kakapo	3565.53	952680	2490.37	**0.698**	749477	**0.787**	1435.99	**0.403**	386342	**0.406**	2144.47	**0.601**	560533	**0.588**
	23.40%	2093245	4569.97	**0.635**	1372207	**0.656**	1559.83	**0.217**	403091	**0.193**	1725.41	**0.240**	472393	**0.226**
	16.19%	2768926	2772.87	**0.385**	895701	**0.323**	0.00%	1.000	2695684	0.974	5927.88	**0.823**	1725439	**0.623**
neos-5114902-kasavu	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
neos-5188808-nattai	1552.46	14414	1541.13	0.993	16039	*1.113*	1264.88	**0.815**	11986	**0.832**	1251.29	**0.806**	12145	**0.843**
	1281.73	12654	1220.92	0.953	12570	0.993	1236.94	0.965	12505	0.988	1292.07	1.008	13554	*1.071*
	1516.90	16075	1593.52	*1.051*	16725	1.040	1638.61	*1.080*	16454	1.024	1380.62	**0.910**	12548	**0.781**
neos-5195221-niemur	5368.93	179683	4134.46	**0.770**	132526	**0.738**	3739.89	**0.697**	66433	**0.370**	2813.87	**0.524**	47466	**0.264**
	5874.02	284617	3249.42	**0.553**	71286	**0.250**	3377.21	**0.575**	28903	**0.102**	2911.85	**0.496**	25010	**0.088**

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	5.01%	354114	3694.26	**0.513**	70193	**0.198**	3307.81	**0.459**	55697	**0.157**	2890.78	**0.401**	33779	**0.095**
neos-631710	14.21%	2	14.21%	1.000	2	1.000	14.21%	1.000	2	1.000	14.21%	1.000	2	1.000
	8.90%	1	8.90%	1.000	3	3.000	8.90%	1.000	5	5.000	8.90%	1.000	4	4.000
	14.21%	2	14.21%	1.000	2	1.000	14.21%	1.000	3	1.500	14.21%	1.000	3	1.500
neos-662469	0.00%	62342	0.00%	1.000	58509	0.939	0.00%	1.000	64188	1.030	0.01%	1.000	59651	0.957
	0.00%	68051	0.06%	1.000	20707	0.304	0.05%	1.000	65664	0.965	0.00%	1.000	50627	0.744
	0.00%	54762	0.01%	1.000	65512	1.196	0.01%	1.000	54495	0.995	0.01%	1.000	56995	1.041
neos-787933	1.39	1	1.35	0.971	1	1.000	1.39	1.000	1	1.000	1.37	0.986	1	1.000
	1.40	1	1.40	1.000	1	1.000	1.38	0.986	1	1.000	1.39	0.993	1	1.000
	1.34	1	1.40	1.045	1	1.000	1.39	1.037	1	1.000	1.41	*1.052*	1	1.000
neos-827175	6.15	1	6.11	0.993	1	1.000	6.11	0.993	1	1.000	6.10	0.992	1	1.000
	8.26	1	8.25	0.999	1	1.000	8.25	0.999	1	1.000	8.21	0.994	1	1.000
	10.20	1	10.21	1.001	1	1.000	10.20	1.000	1	1.000	10.23	1.003	1	1.000
neos-848589	32.63%	274	32.79%	1.000	300	1.095	32.15%	1.000	260	0.949	32.15%	1.000	256	0.934
	42.57%	159	42.95%	1.000	148	0.931	42.95%	1.000	148	0.931	42.95%	1.000	148	0.931
	45.78%	183	46.27%	1.000	179	0.978	45.78%	1.000	106	0.579	46.27%	1.000	106	0.579
neos-860300	22.39	4	22.44	1.002	5	*1.250*	17.24	**0.770**	3	**0.750**	17.27	**0.771**	2	**0.500**
	13.92	2	13.68	0.983	2	1.000	13.56	0.974	2	1.000	13.35	0.959	2	1.000
	13.70	2	15.60	*1.139*	2	1.000	23.47	*1.713*	3	*1.500*	23.18	*1.692*	3	*1.500*
neos-873061	9.28%	161	9.28%	1.000	159	0.988	9.28%	1.000	158	0.981	9.28%	1.000	155	0.963
	7.62%	145	7.72%	1.000	145	1.000	7.62%	1.000	150	1.034	7.72%	1.000	148	1.021
	6.14%	170	8.12%	1.000	170	1.000	6.14%	1.000	168	0.988	8.12%	1.000	168	0.988
neos-911970	0.36%	2189398	0.37%	1.000	1925708	0.880	0.15%	1.000	3351711	1.531	1.05%	1.000	1400854	0.640
	5.62%	1896518	2.04%	1.000	1841141	0.971	2.43%	1.000	2313331	1.220	2.49%	1.000	1814127	0.957
	0.06%	8303204	0.05%	1.000	8547758	1.029	0.06%	1.000	7659721	0.923	0.06%	1.000	11460910	1.380
neos-933966	1389.95	113	0.00%	5.180	1948	17.239	3139.55	*2.259*	425	*3.761*	1374.28	0.989	138	*1.221*
	1515.32	121	2909.77	*1.920*	292	*2.413*	1572.20	1.038	476	*3.934*	848.27	**0.560**	38	**0.314**
	2515.32	846	1869.44	**0.743**	757	**0.895**	1298.27	**0.516**	86	**0.102**	2180.73	**0.867**	283	**0.335**
neos-950242	100.00%	9788	100.00%	1.000	9731	0.994	100.00%	1.000	8107	0.828	100.00%	1.000	9288	0.949
	100.00%	9395	100.00%	1.000	9278	0.988	100.00%	1.000	7684	0.818	100.00%	1.000	8446	0.899
	100.00%	16489	100.00%	1.000	15600	0.946	100.00%	1.000	15869	0.962	100.00%	1.000	15629	0.948
neos-957323	50.68	2	51.16	1.009	2	1.000	85.94	*1.696*	2	1.000	86.06	*1.698*	2	1.000
	273.76	22	229.61	**0.839**	22	1.000	110.39	**0.403**	5	**0.227**	110.59	**0.404**	5	**0.227**
	55.25	1	55.36	1.002	1	1.000	79.87	*1.446*	2	*2.000*	80.10	*1.450*	2	*2.000*

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
neos-960392	1233.09	54	1229.34	0.997	54	1.000	878.66	**0.713**	15	**0.278**	881.09	**0.715**	15	**0.278**
	1355.33	88	1354.38	0.999	88	1.000	1453.26	*1.072*	102	*1.159*	1439.63	*1.062*	102	*1.159*
	2253.06	109	2241.76	0.995	109	1.000	1336.08	**0.593**	403	*3.697*	1363.87	**0.605**	403	*3.697*
neos17	541.86	806050	1106.75	*2.043*	1455127	*1.805*	14.74	**0.027**	10823	**0.013**	25.95	**0.048**	22460	**0.028**
	449.30	626324	196.55	**0.437**	216740	**0.346**	8.75	**0.019**	5398	**0.009**	9.39	**0.021**	5644	**0.009**
	200.05	247116	4928.16	*24.635*	6947962	*28.116*	8.75	**0.044**	5985	**0.024**	9.84	**0.049**	6376	**0.026**
neos5	1530.99	5010106	1273.04	**0.832**	4146144	**0.828**	1193.25	**0.779**	3963527	**0.791**	1007.54	**0.658**	3292114	**0.657**
	1875.51	6735352	1890.98	1.008	6650076	0.987	1519.55	**0.810**	5189427	**0.770**	1234.24	**0.658**	4202380	**0.624**
	2039.35	7377371	1936.64	**0.950**	6917171	**0.938**	1552.44	**0.761**	5422762	**0.735**	1183.51	**0.580**	4100005	**0.556**
neos859080	∞	15987332	0.00%	1.000	15703476	0.982	0.53	**0.000**	875	**0.000**	0.50	**0.000**	792	**0.000**
	∞	16107026	0.00%	1.000	15732597	0.977	0.50	**0.000**	554	**0.000**	0.54	**0.000**	655	**0.000**
	∞	16561424	0.00%	1.000	16195339	0.978	0.57	**0.000**	600	**0.000**	0.55	**0.000**	565	**0.000**
neos8	1.94	1	1.95	1.005	1	1.000	1.91	0.985	1	1.000	1.95	1.005	1	1.000
	1.82	1	1.83	1.005	1	1.000	1.80	0.989	1	1.000	1.89	1.038	1	1.000
	1.80	1	1.80	1.000	1	1.000	1.82	1.011	1	1.000	1.83	1.017	1	1.000
net12	2640.96	3164	2699.23	1.022	3563	*1.126*	1806.86	**0.684**	1650	**0.521**	1842.42	**0.698**	1211	**0.383**
	1019.70	3717	875.61	**0.859**	3088	**0.831**	1570.29	*1.540*	1687	**0.454**	1631.28	*1.600*	1816	**0.489**
	4039.07	4690	2087.97	**0.517**	4963	*1.058*	954.82	**0.236**	2731	**0.582**	1561.43	**0.387**	1695	**0.361**
netdiversion	853.05	43	901.21	*1.056*	43	1.000	894.09	1.048	43	1.000	848.00	0.994	43	1.000
	899.72	47	899.25	0.999	47	1.000	2374.72	*2.639*	88	*1.872*	2364.82	*2.628*	88	*1.872*
	1143.57	27	1370.90	*1.199*	58	*2.148*	1716.75	*1.501*	51	*1.889*	1087.12	0.951	27	1.000
nexp-150-20-8-5	0.75%	20022	0.00%	1.000	14956	0.747	4440.55	**0.617**	9628	**0.481**	3539.59	**0.492**	5786	**0.289**
	2624.56	5582	2712.74	1.034	6896	*1.235*	3420.50	*1.303*	6115	*1.095*	3635.13	*1.385*	7166	*1.284*
	2245.93	4565	3428.03	*1.526*	10097	*2.212*	5386.25	*2.398*	10647	*2.332*	0.83%	3.206	13054	2.860
ns1116954	∞	49	∞	1.000	54	1.102	∞	1.000	41	0.837	∞	1.000	32	0.653
	∞	52	∞	1.000	46	0.885	∞	1.000	32	0.615	∞	1.000	57	1.096
	∞	66	∞	1.000	66	1.000	∞	1.000	72	1.091	∞	1.000	75	1.136
ns1208400	1325.08	10259	744.51	**0.562**	3153	**0.307**	1818.68	*1.373*	4814	**0.469**	419.49	**0.317**	2004	**0.195**
	2649.91	5713	2012.44	**0.759**	18219	*3.189*	969.97	**0.366**	2481	**0.434**	683.06	**0.258**	2339	**0.409**
	2961.80	8352	1275.03	**0.430**	4061	**0.486**	1789.77	**0.604**	7679	**0.919**	1074.09	**0.363**	2315	**0.277**
ns1644855	2955.01	14	3271.29	*1.107*	14	1.000	0.00%	2.437	77	5.500	7.37%	2.437	36	2.571
	2058.74	1	1530.45	**0.743**	1	1.000	0.00%	3.497	60	60.000	7.37%	3.497	79	79.000
	982.60	1	1015.27	1.033	1	1.000	973.54	0.991	1	1.000	974.47	0.992	1	1.000
ns1760995	58.41%	1	58.41%	1.000	1	1.000	58.41%	1.000	1	1.000	58.41%	1.000	1	1.000

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Table A.1: Detailed computational results on Miplib 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	71.46%	1	71.46%	1.000	1	1.000	71.46%	1.000	1	1.000	71.46%	1.000	1	1.000
	48.93%	1	48.93%	1.000	1	1.000	49.34%	1.000	1	1.000	48.93%	1.000	1	1.000
ns1830653	250.48	11010	169.53	**0.677**	9714	**0.882**	231.80	**0.925**	13180	*1.197*	287.45	*1.148*	14558	*1.322*
	214.45	10080	191.04	**0.891**	7290	**0.723**	136.63	**0.637**	6054	**0.601**	134.33	**0.626**	7527	**0.747**
	229.69	11146	123.71	**0.539**	5660	**0.508**	153.90	**0.670**	9327	**0.837**	148.24	**0.645**	7267	**0.652**
ns1952667	1171.28	20047	0.00%	6.147	67996	3.392	1170.98	1.000	5921	**0.295**	∞	6.147	52208	2.604
	6250.77	62041	5036.79	**0.806**	57160	**0.921**	0.00%	1.152	63181	1.018	1392.38	**0.223**	9508	**0.153**
	∞	83514	0.00%	1.000	87894	1.052	768.05	**0.107**	3203	**0.038**	968.90	**0.135**	4900	**0.059**
nu25-pr12	6.01	97	6.29	1.047	97	1.000	5.30	**0.882**	53	**0.546**	5.36	**0.892**	53	**0.546**
	6.86	63	7.19	1.048	65	1.032	6.02	**0.878**	66	1.048	6.11	**0.891**	66	1.048
	6.09	14	6.33	1.039	26	*1.857*	6.00	0.985	16	*1.143*	6.05	0.993	16	*1.143*
nursesched-medium-hint03	4946.81%	1648	1453.90%	1.000	1442	0.875	2123.61%	1.000	1421	0.862	1657.78%	1.000	1100	0.667
	1030.86%	1061	1383.83%	1.000	1228	1.157	776.84%	1.000	1371	1.292	3021.25%	1.000	2050	1.932
	298.27%	1435	620.98%	1.000	959	0.668	437.46%	1.000	1287	0.897	1077.84%	1.000	1121	0.781
nursesched-sprint02	201.19	509	203.92	1.014	553	*1.086*	140.76	**0.700**	378	**0.743**	142.08	**0.706**	370	**0.727**
	76.96	236	77.30	1.004	236	1.000	85.08	*1.106*	409	*1.733*	85.18	*1.107*	409	*1.733*
	59.67	95	59.82	1.003	95	1.000	67.53	*1.132*	222	*2.337*	67.71	*1.135*	222	*2.337*
nw04	34.11	7	37.53	*1.100*	6	**0.857**	38.28	*1.122*	10	*1.429*	37.93	*1.112*	6	**0.857**
	26.14	4	31.08	*1.189*	5	*1.250*	26.14	1.000	4	1.000	31.39	*1.201*	5	*1.250*
	31.72	6	35.19	*1.109*	6	1.000	32.08	1.011	6	1.000	35.16	*1.108*	6	1.000
opm2-z10-s4	27.22%	904	26.97%	1.000	904	1.000	27.22%	1.000	1081	1.196	24.70%	1.000	1000	1.106
	26.34%	621	27.07%	1.000	619	0.997	26.34%	1.000	620	0.998	27.76%	1.000	586	0.944
	36.42%	1081	24.75%	1.000	972	0.899	32.55%	1.000	1165	1.078	26.96%	1.000	1015	0.939
p200x1188c	3.56	2	3.48	0.978	2	1.000	3.55	0.997	2	1.000	3.53	0.992	2	1.000
	4.00	3	4.00	1.000	3	1.000	4.08	1.020	4	*1.333*	3.96	0.990	3	1.000
	3.60	2	3.57	0.992	2	1.000	3.62	1.006	2	1.000	3.62	1.006	2	1.000
peg-solitaire-a3	∞	3925	∞	1.000	3933	1.002	∞	1.000	5443	1.387	∞	1.000	5752	1.465
	∞	7301	∞	1.000	7171	0.982	∞	1.000	3107	0.426	∞	1.000	3557	0.487
	∞	4215	∞	1.000	4213	1.000	∞	1.000	4410	1.046	∞	1.000	3969	0.942
pg5_34	1126.04	143283	1239.19	*1.100*	149528	1.044	1259.57	*1.119*	157415	*1.099*	1173.22	1.042	148717	1.038
	1182.23	154044	1146.23	0.970	143927	**0.934**	1253.87	*1.061*	169115	*1.098*	1134.07	0.959	144543	**0.938**
	1340.20	158399	1672.40	*1.248*	201264	*1.271*	1778.08	*1.327*	195261	*1.233*	1085.15	**0.810**	121673	**0.768**
pg	105.83	2467	117.28	*1.108*	3921	*1.589*	107.89	1.019	2467	1.000	101.85	0.962	2687	*1.089*
	104.92	1059	85.91	**0.819**	1372	*1.296*	106.33	1.013	1059	1.000	86.23	**0.822**	1372	*1.296*

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	111.36	1127	106.75	0.959	2311	*2.051*	112.91	1.014	1127	1.000	107.44	0.965	2311	*2.051*
physicianscheduling3-3	∞	304	∞	1.000	364	1.197	∞	1.000	232	0.763	∞	1.000	415	1.365
	∞	723	∞	1.000	706	0.976	∞	1.000	161	0.223	∞	1.000	313	0.433
	∞	136	∞	1.000	146	1.074	∞	1.000	325	2.390	∞	1.000	361	2.654
physicianscheduling6-2	201.15	1019	228.21	*1.135*	927	**0.910**	149.40	**0.743**	661	**0.649**	124.81	**0.620**	377	**0.370**
	335.55	1031	165.12	**0.492**	159	**0.154**	3785.01	*11.280*	756	**0.733**	462.02	*1.377*	2804	*2.720*
	45.04	1	44.88	0.996	1	1.000	44.69	0.992	1	1.000	44.74	0.993	1	1.000
piperout-08	867.40	161	1107.65	*1.277*	201	*1.248*	1053.28	*1.214*	316	*1.963*	797.03	**0.919**	130	**0.807**
	674.29	2169	589.39	**0.874**	409	**0.189**	626.88	**0.930**	797	**0.367**	606.54	**0.900**	552	**0.254**
	1096.60	1093	1152.90	*1.051*	926	**0.847**	664.35	**0.606**	123	**0.113**	923.85	**0.842**	596	**0.545**
piperout-27	140.65	2	140.54	0.999	2	1.000	140.31	0.998	2	1.000	140.11	0.996	2	1.000
	708.74	1201	224.78	**0.317**	475	**0.396**	428.30	**0.604**	753	**0.627**	275.91	**0.389**	566	**0.471**
	252.43	131	322.96	*1.279*	81	**0.618**	254.43	1.008	125	0.954	332.32	*1.316*	72	**0.550**
pk1	108.10	307068	120.53	*1.115*	346969	*1.130*	105.74	0.978	302166	0.984	107.55	0.995	301100	0.981
	114.56	340000	105.97	**0.925**	324036	0.953	121.02	*1.056*	355700	1.046	109.16	0.953	317026	**0.932**
	105.07	313662	109.87	1.046	322736	1.029	108.50	1.033	319989	1.020	112.34	*1.069*	328715	1.048
proteindesign121hz512p9	7.04%	711	12.82%	1.000	1105	1.554	11.56%	1.000	566	0.796	9.60%	1.000	591	0.831
	94.35%	30	13.92%	1.000	30	1.000	94.35%	1.000	435	14.500	7.94%	1.000	440	14.667
	19.25%	727	26.02%	1.000	929	1.278	23.91%	1.000	593	0.816	26.02%	1.000	593	0.816
proteindesign122trx11p8	1.98%	4	1.82%	1.000	4	1.000	1.91%	1.000	126	31.500	1.95%	1.000	3	0.750
	2.03%	100	1.99%	1.000	36	0.360	1.90%	1.000	4	0.040	1.91%	1.000	8	0.080
	1.91%	3	1.86%	1.000	4	1.333	1.94%	1.000	4	1.333	1.93%	1.000	17	5.667
qap10	86.95	3	87.28	1.004	3	1.000	88.00	1.012	3	1.000	87.99	1.012	3	1.000
	101.05	3	101.22	1.002	3	1.000	112.08	*1.109*	5	*1.667*	111.82	*1.107*	5	*1.667*
	175.11	14	175.10	1.000	14	1.000	197.20	*1.126*	15	*1.071*	197.87	*1.130*	15	*1.071*
radiationm18-12-05	7.43%	562171	5.59%	1.000	515540	0.917	12.99%	1.000	461442	0.821	12.99%	1.000	479812	0.853
	20.42%	501574	7.44%	1.000	397542	0.793	12.99%	1.000	637161	1.270	0.05%	1.000	750150	1.496
	13.00%	650099	0.04%	1.000	504948	0.777	5.60%	1.000	511409	0.787	1.89%	1.000	551080	0.848
radiationm40-10-02	29.91%	62981	27.84%	1.000	58593	0.930	53.62%	1.000	86978	1.381	67.02%	1.000	53316	0.847
	38.16%	67121	100.01%	1.000	103154	1.537	19.60%	1.000	48285	0.719	57.74%	1.000	27109	0.404
	37.12%	100900	43.31%	1.000	68901	0.683	21.66%	1.000	32312	0.320	22.69%	1.000	99008	0.981
rail01	2.42%	103	3.14%	1.000	204	1.981	2.95%	1.000	203	1.971	2.74%	1.000	200	1.942
	12.05%	100	8.83%	1.000	135	1.350	6.70%	1.000	208	2.080	25.21%	1.000	182	1.820
	6.73%	204	∞	1.000	187	0.917	6.73%	1.000	50	0.245	7.32%	1.000	183	0.897

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Table A.1: Detailed computational results on Miplib 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
rail02	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
rail507	160.45	671	165.79	1.033	671	1.000	152.03	**0.948**	623	**0.928**	156.67	0.976	623	**0.928**
	182.35	825	185.49	1.017	841	1.019	178.18	0.977	807	0.978	180.04	0.987	783	**0.949**
	185.01	737	183.61	0.992	733	0.995	188.09	1.017	783	*1.062*	193.43	1.046	771	1.046
ran14x18-disj-8	1734.22	641683	1540.83	**0.888**	578285	**0.901**	1734.57	1.000	649217	1.012	2109.62	*1.216*	656920	1.024
	1268.41	472072	1387.32	*1.094*	451943	0.957	1545.12	*1.218*	411381	**0.871**	1785.31	*1.408*	564900	*1.197*
	1758.43	721480	1832.39	1.042	676165	**0.937**	1742.65	0.991	650929	**0.902**	1694.59	0.964	593570	**0.823**
rd-rplusc-21	≥ 10000%	290601	∞	1.000	365951	1.259	∞	1.000	684731	2.356	≥ 10000%	1.000	484631	1.668
	∞	352151	≥ 10000%	1.000	303110	0.861	∞	1.000	640758	1.820	≥ 10000%	1.000	737139	2.093
	∞	339770	≥ 10000%	1.000	292219	0.860	∞	1.000	719051	2.116	≥ 10000%	1.000	763715	2.248
reblock115	0.19%	1292105	0.08%	1.000	1121470	0.868	0.26%	1.000	849098	0.657	4390.48	**0.610**	704168	**0.545**
	0.19%	927963	0.13%	1.000	947601	1.021	0.19%	1.000	1243005	1.339	6605.46	**0.917**	882785	0.951
	0.25%	829733	0.14%	1.000	909121	1.096	0.18%	1.000	854950	1.030	5894.68	**0.819**	832788	1.004
rmatr100-p10	153.43	787	155.34	1.012	787	1.000	166.59	*1.086*	809	1.028	166.48	*1.085*	809	1.028
	161.02	812	165.33	1.027	812	1.000	161.08	1.000	822	1.012	162.84	1.011	822	1.012
	157.46	795	157.99	1.003	795	1.000	158.36	1.006	783	0.985	160.62	1.020	827	1.040
rmatr200-p5	21.27%	404	22.40%	1.000	400	0.990	21.27%	1.000	420	1.040	22.40%	1.000	421	1.042
	19.25%	429	19.56%	1.000	429	1.000	19.25%	1.000	431	1.005	19.56%	1.000	423	0.986
	21.58%	369	21.08%	1.000	369	1.000	21.58%	1.000	395	1.070	21.08%	1.000	403	1.092
rocI-4-11	1462.33	27778	1677.53	*1.147*	34270	*1.234*	658.34	**0.450**	12460	**0.449**	638.21	**0.436**	12970	**0.467**
	953.34	15737	995.45	1.044	15604	0.992	906.63	0.951	14955	0.950	1001.80	*1.051*	17602	*1.119*
	686.49	12985	703.24	1.024	13366	1.029	483.27	**0.704**	8950	**0.689**	498.07	**0.726**	9550	**0.735**
rocII-5-11	153.78%	3278	108.23%	1.000	3225	0.984	108.85%	1.000	3338	1.018	108.52%	1.000	3399	1.037
	109.17%	2981	108.84%	1.000	2796	0.938	153.85%	1.000	2754	0.924	109.87%	1.000	2764	0.927
	109.73%	3581	77.57%	1.000	3567	0.996	153.96%	1.000	2955	0.825	109.11%	1.000	2522	0.704
rococoB10-011000	14.19%	154404	13.62%	1.000	155341	1.006	14.38%	1.000	158057	1.024	13.71%	1.000	151103	0.979
	16.15%	157983	15.23%	1.000	163365	1.034	17.58%	1.000	156695	0.992	15.09%	1.000	143253	0.907
	13.34%	137952	12.65%	1.000	157492	1.142	14.89%	1.000	160008	1.160	12.80%	1.000	153839	1.115
rococoC10-001000	747.13	47028	1007.88	*1.349*	63164	*1.343*	1405.24	*1.881*	91581	*1.947*	765.76	1.025	53303	*1.133*
	706.86	64338	787.50	*1.114*	51175	**0.795**	726.91	1.028	54559	**0.848**	851.99	*1.205*	63090	0.981
	1271.19	115469	1345.55	*1.058*	125085	*1.083*	1454.78	*1.144*	105955	**0.918**	1626.91	*1.280*	162527	*1.408*
roi2alpha3n4	1512.25	15007	1606.73	*1.062*	15325	1.021	1638.42	*1.083*	14967	0.997	1424.80	**0.942**	12529	**0.835**

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1960.77	18735	1941.17	0.990	17209	**0.919**	2268.33	*1.157*	21011	*1.121*	1940.46	0.990	17446	**0.931**
	1497.10	13689	1533.64	1.024	13689	1.000	1479.60	0.988	13303	0.972	1486.54	0.993	13303	0.972
roi5alpha10n8	37.63%	5830	34.26%	1.000	5642	0.968	34.00%	1.000	5450	0.935	35.37%	1.000	5989	1.027
	36.08%	5044	33.05%	1.000	6515	1.292	36.27%	1.000	6084	1.206	40.36%	1.000	6346	1.258
	32.13%	7542	32.06%	1.000	6705	0.889	39.79%	1.000	6951	0.922	32.14%	1.000	6789	0.900
roll3000	52.27	2881	46.99	**0.899**	3349	*1.162*	32.73	**0.626**	1335	**0.463**	36.86	**0.705**	1986	**0.689**
	61.33	3675	46.03	**0.751**	2170	**0.590**	38.03	**0.620**	1831	**0.498**	38.91	**0.634**	2149	**0.585**
	37.85	2629	41.29	*1.091*	1582	**0.602**	79.32	*2.096*	5947	*2.262*	60.26	*1.592*	3736	*1.421*
s100	3.09%	21	5.53%	1.000	21	1.000	3.09%	1.000	20	0.952	5.53%	1.000	20	0.952
	3.58%	32	29.84%	1.000	32	1.000	3.58%	1.000	17	0.531	29.84%	1.000	17	0.531
	1.06%	43	1.06%	1.000	43	1.000	1.06%	1.000	22	0.512	1.06%	1.000	22	0.512
s250r10	0.27%	83749	0.00%	1.000	23252	0.278	4304.43	**0.598**	45624	**0.545**	0.28%	1.000	22897	0.273
	6570.42	54164	0.00%	1.096	62268	1.150	6899.93	*1.050*	61772	*1.140*	6366.45	0.969	45426	**0.839**
	0.19%	45392	0.23%	1.000	34660	0.764	0.23%	1.000	34214	0.754	0.23%	1.000	31811	0.701
satellites2-40	∞	61	∞	1.000	65	1.066	∞	1.000	20	0.328	∞	1.000	19	0.311
	∞	5	∞	1.000	5	1.000	∞	1.000	4	0.800	∞	1.000	4	0.800
	∞	29	70.59%	1.000	29	1.000	∞	1.000	33	1.138	70.59%	1.000	33	1.138
satellites2-60-fs	∞	36	∞	1.000	47	1.306	∞	1.000	162	4.500	∞	1.000	33	0.917
	∞	23	∞	1.000	34	1.478	∞	1.000	39	1.696	∞	1.000	137	5.957
	∞	27	∞	1.000	236	8.741	123.08%	1.000	28	1.037	∞	1.000	28	1.037
savsched1	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
sct2	0.04%	954820	0.03%	1.000	634745	0.665	0.05%	1.000	888872	0.931	0.03%	1.000	600226	0.629
	0.03%	754716	0.05%	1.000	1052466	1.395	0.03%	1.000	573672	0.760	0.05%	1.000	659682	0.874
	0.05%	987702	0.03%	1.000	876985	0.888	0.05%	1.000	1113822	1.128	0.03%	1.000	994927	1.007
seymour1	72.90	1334	86.90	*1.192*	1624	*1.217*	77.19	*1.059*	1274	0.955	90.45	*1.241*	1627	*1.220*
	63.65	1541	64.87	1.019	1498	0.972	68.14	*1.071*	1473	0.956	67.90	*1.067*	1466	0.951
	70.25	1682	66.94	0.953	1597	**0.949**	73.58	1.047	1685	1.002	72.05	1.026	1822	*1.083*
seymour	0.72%	184607	0.71%	1.000	184455	0.999	0.72%	1.000	212029	1.149	0.66%	1.000	242500	1.314
	0.70%	218467	0.75%	1.000	237161	1.086	0.67%	1.000	182768	0.837	0.68%	1.000	222209	1.017
	0.66%	244475	0.68%	1.000	263532	1.078	0.64%	1.000	257621	1.054	0.74%	1.000	225373	0.922
sing326	0.28%	7428	0.21%	1.000	7300	0.983	0.28%	1.000	11141	1.500	0.15%	1.000	11755	1.583
	0.17%	7972	0.14%	1.000	4305	0.540	0.21%	1.000	7015	0.880	0.17%	1.000	8196	1.028

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Table A.1: Detailed computational results on Miplib 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.13%	7276	0.31%	1.000	7051	0.969	0.13%	1.000	8191	1.126	0.32%	1.000	7997	1.099
sing44	0.34%	7528	0.50%	1.000	7387	0.981	0.35%	1.000	8051	1.069	0.45%	1.000	5531	0.735
	0.17%	5935	0.19%	1.000	5781	0.974	0.17%	1.000	7467	1.258	0.19%	1.000	7349	1.238
	0.25%	2788	0.27%	1.000	2746	0.985	0.25%	1.000	2361	0.847	0.27%	1.000	2267	0.813
snp-02-004-104	0.00%	9410	0.00%	1.000	7582	0.806	0.00%	1.000	13298	1.413	0.00%	1.000	14561	1.547
	0.00%	18306	0.00%	1.000	16194	0.885	0.00%	1.000	18299	1.000	0.00%	1.000	18040	0.985
	0.00%	19513	0.00%	1.000	18196	0.933	0.00%	1.000	20219	1.036	0.00%	1.000	19680	1.009
sorrell3	27.41%	15430	43.81%	1.000	15364	0.996	27.41%	1.000	41057	2.661	43.81%	1.000	41208	2.671
	19.33%	14447	35.61%	1.000	15273	1.057	19.26%	1.000	39273	2.718	35.59%	1.000	39514	2.735
	19.14%	11518	19.11%	1.000	11504	0.999	19.14%	1.000	8978	0.779	19.11%	1.000	8801	0.764
sp150x300d	4.07	3843	4.20	1.032	3843	1.000	3.98	0.978	3472	**0.903**	3.96	0.973	3472	**0.903**
	5.59	5283	5.71	1.021	5283	1.000	3.10	**0.555**	2569	**0.486**	3.12	**0.558**	2569	**0.486**
	1.16	825	1.15	0.991	825	1.000	1.34	*1.155*	848	1.028	1.29	*1.112*	848	1.028
sp97ar	0.86%	26468	0.95%	1.000	19967	0.754	1.18%	1.000	16911	0.639	0.98%	1.000	15747	0.595
	1.21%	22185	0.99%	1.000	21650	0.976	1.19%	1.000	28768	1.297	1.02%	1.000	22961	1.035
	1.57%	27393	1.51%	1.000	25908	0.946	1.94%	1.000	35662	1.302	1.53%	1.000	24828	0.906
sp98ar	0.55%	55288	0.80%	1.000	50893	0.921	1.07%	1.000	70090	1.268	1.43%	1.000	71746	1.298
	0.50%	43725	0.75%	1.000	60167	1.376	0.63%	1.000	57589	1.317	0.48%	1.000	67060	1.534
	0.63%	63020	1.26%	1.000	73947	1.173	0.58%	1.000	76587	1.215	0.98%	1.000	71271	1.131
splice1k1	6524.11	1136	307.70%	1.104	1025	0.902	304.48%	1.104	1365	1.202	309.20%	1.104	513	0.452
	308.22%	181	305.76%	1.000	687	3.796	306.15%	1.000	888	4.906	376.10%	1.000	594	3.282
	4825.07	381	0.00%	1.492	889	2.333	4823.00	1.000	580	*1.522*	358.74%	1.492	834	2.189
square41	80.44%	60	109.98%	1.000	60	1.000	80.44%	1.000	30	0.500	109.98%	1.000	30	0.500
	92.32%	21	92.32%	1.000	12	0.571	92.32%	1.000	9	0.429	89.32%	1.000	37	1.762
	78.32%	17	92.32%	1.000	17	1.000	78.32%	1.000	31	1.824	92.32%	1.000	28	1.647
square47	231.21%	4	231.21%	1.000	4	1.000	231.21%	1.000	4	1.000	231.21%	1.000	4	1.000
	231.21%	12	117.00%	1.000	12	1.000	231.21%	1.000	13	1.083	117.00%	1.000	13	1.083
	151.26%	5	231.21%	1.000	5	1.000	151.26%	1.000	2	0.400	231.21%	1.000	1	0.200
supportcase10	813.36%	1	803.51%	1.000	1	1.000	813.36%	1.000	1	1.000	803.51%	1.000	1	1.000
	934.71%	1	989.07%	1.000	1	1.000	934.71%	1.000	1	1.000	989.07%	1.000	1	1.000
	476.90%	15	1054.36%	1.000	15	1.000	476.90%	1.000	1	0.067	1054.36%	1.000	1	0.067
supportcase12	1.36%	1410	1.31%	1.000	1413	1.002	1.22%	1.000	1434	1.017	1.31%	1.000	1463	1.038
	1.09%	1482	1.35%	1.000	1482	1.000	1.09%	1.000	2297	1.550	1.35%	1.000	2297	1.550
	1.17%	1356	1.13%	1.000	1346	0.993	1.17%	1.000	1181	0.871	1.30%	1.000	1505	1.110

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
supportcase18	5.96%	218901	3.84%	1.000	240308	1.098	3.84%	1.000	423514	1.935	3.84%	1.000	419350	1.916
	3.84%	314488	5.96%	1.000	310588	0.988	3.84%	1.000	173247	0.551	5.96%	1.000	237591	0.755
	3.84%	408888	3.84%	1.000	429055	1.049	5.96%	1.000	248417	0.608	3.84%	1.000	198815	0.486
supportcase19	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	∞	1.000	1	1.000
supportcase22	∞	51	∞	1.000	51	1.000	∞	1.000	51	1.000	∞	1.000	51	1.000
	∞	18	∞	1.000	18	1.000	∞	1.000	18	1.000	∞	1.000	18	1.000
	∞	66	∞	1.000	66	1.000	∞	1.000	66	1.000	∞	1.000	66	1.000
supportcase26	7.35%	8115772	6.78%	1.000	8417897	1.037	6.39%	1.000	7850135	0.967	8.94%	1.000	8135621	1.002
	3848.74	4970066	6504.62	*1.690*	8335546	*1.677*	2878.57	**0.748**	3631376	**0.731**	5238.22	*1.361*	6761735	*1.360*
	3833.68	4290344	4861.79	*1.268*	6229516	*1.452*	3369.62	**0.879**	3710979	**0.865**	4487.28	*1.170*	5497025	*1.281*
supportcase33	2909.49	29028	620.26	**0.213**	4319	**0.149**	726.92	**0.250**	5039	**0.174**	1598.38	**0.549**	12756	**0.439**
	6808.00	104552	921.34	**0.135**	8143	**0.078**	2587.40	**0.380**	14983	**0.143**	1600.98	**0.235**	7176	**0.069**
	1885.13	13657	6423.38	*3.407*	100498	*7.359*	2300.97	*1.221*	15069	*1.103*	682.16	**0.362**	3786	**0.277**
supportcase40	998.95	10137	913.72	**0.915**	8676	**0.856**	783.23	**0.784**	6335	**0.625**	786.50	**0.787**	6335	**0.625**
	1101.47	9647	1116.91	1.014	10003	1.037	890.01	**0.808**	7377	**0.765**	946.94	**0.860**	7991	**0.828**
	1120.16	11437	851.23	**0.760**	6856	**0.599**	789.34	**0.705**	6970	**0.609**	797.74	**0.712**	6970	**0.609**
supportcase42	0.17%	483736	0.38%	1.000	508591	1.051	0.16%	1.000	475045	0.982	0.38%	1.000	305571	0.632
	0.11%	373134	0.11%	1.000	497093	1.332	0.13%	1.000	522907	1.401	0.10%	1.000	380155	1.019
	0.25%	340848	0.51%	1.000	325417	0.955	0.32%	1.000	329921	0.968	0.35%	1.000	467610	1.372
supportcase6	8.59%	24612	8.85%	1.000	21058	0.856	8.75%	1.000	19919	0.809	9.13%	1.000	18980	0.771
	9.57%	14957	8.97%	1.000	13831	0.925	9.51%	1.000	14324	0.958	8.41%	1.000	17726	1.185
	7.93%	32655	9.72%	1.000	28462	0.872	8.14%	1.000	18358	0.562	9.72%	1.000	17709	0.542
supportcase7	177.71	88	178.05	1.002	88	1.000	180.55	1.016	59	**0.670**	179.98	1.013	59	**0.670**
	191.37	47	191.68	1.002	45	0.957	191.66	1.002	47	1.000	193.62	1.012	45	0.957
	205.05	32	210.36	1.026	32	1.000	206.60	1.008	32	1.000	210.25	1.025	32	1.000
swath1	12.81	304	20.92	*1.633*	351	*1.155*	16.14	*1.260*	319	1.049	21.09	*1.646*	281	**0.924**
	13.87	451	18.91	*1.363*	451	1.000	14.10	1.017	257	**0.570**	17.34	*1.250*	245	**0.543**
	11.74	278	15.91	*1.355*	292	*1.050*	14.05	*1.197*	260	**0.935**	19.82	*1.688*	292	*1.050*
swath3	112.15	17832	178.65	*1.593*	24564	*1.378*	204.18	*1.821*	31466	*1.765*	226.20	*2.017*	28316	*1.588*
	687.17	169323	701.79	1.021	139518	**0.824**	151.94	**0.221**	21468	**0.127**	182.91	**0.266**	21837	**0.129**
	645.63	170136	155.37	**0.241**	24161	**0.142**	265.56	**0.411**	52338	**0.308**	427.45	**0.662**	74192	**0.436**
tbfp-network	1556.06	90	1553.30	0.998	90	1.000	2338.83	*1.503*	574	*6.378*	2356.81	*1.515*	574	*6.378*

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Table A.1: Detailed computational results on Miplib 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	932.14	51	934.26	1.002	51	1.000	1695.18	*1.819*	71	*1.392*	1683.80	*1.806*	71	*1.392*
	1125.11	105	1128.84	1.003	105	1.000	1095.63	0.974	99	**0.943**	1088.57	0.968	99	**0.943**
thor50dday	23.05%	102	23.30%	1.000	98	0.961	23.30%	1.000	95	0.931	23.30%	1.000	95	0.931
	21.49%	12	21.49%	1.000	12	1.000	21.49%	1.000	13	1.083	21.49%	1.000	12	1.000
	14.80%	34	14.80%	1.000	34	1.000	14.80%	1.000	32	0.941	14.80%	1.000	34	1.000
timtab1	86.61	71271	77.62	**0.896**	57256	**0.803**	62.47	**0.721**	51558	**0.723**	73.73	**0.851**	64175	**0.900**
	101.95	90517	84.55	**0.829**	69808	**0.771**	83.32	**0.817**	69075	**0.763**	67.90	**0.666**	51540	**0.569**
	79.25	69505	85.22	*1.075*	70064	1.008	54.95	**0.693**	44058	**0.634**	70.92	**0.895**	55054	**0.792**
tr12-30	788.90	550004	646.27	**0.819**	454361	**0.826**	873.86	*1.108*	593676	*1.079*	606.97	**0.769**	423661	**0.770**
	433.39	328598	695.20	*1.604*	512264	*1.559*	517.81	*1.195*	375059	*1.141*	650.32	*1.501*	475420	*1.447*
	445.40	237285	411.44	**0.924**	237300	1.000	473.86	*1.064*	255026	*1.075*	397.52	**0.893**	213946	**0.902**
traininstance2	∞	60374	$\geq$ 10000%	1.000	58031	0.961	∞	1.000	52932	0.877	∞	1.000	67099	1.111
	∞	41711	∞	1.000	62456	1.497	∞	1.000	60702	1.455	∞	1.000	52063	1.248
	$\geq$ 10000%	75652	∞	1.000	71547	0.946	$\geq$ 10000%	1.000	56732	0.750	6286.13%	1.000	73138	0.967
traininstance6	651.06%	508702	617.72%	1.000	323370	0.636	714.57%	1.000	586788	1.154	634.16%	1.000	456248	0.897
	754.81%	391905	705.98%	1.000	381081	0.972	564.90%	1.000	393074	1.003	626.92%	1.000	347529	0.887
	809.94%	386240	969.81%	1.000	440921	1.142	650.00%	1.000	305257	0.790	520.12%	1.000	454368	1.176
trento1	0.53%	54335	0.11%	1.000	35868	0.660	0.50%	1.000	56381	1.038	0.07%	1.000	57766	1.063
	0.10%	57080	0.08%	1.000	35767	0.627	0.89%	1.000	74643	1.308	0.10%	1.000	51033	0.894
	0.10%	46635	2.44%	1.000	37088	0.795	0.10%	1.000	35614	0.764	1.67%	1.000	35013	0.751
triptim1	1111.72	8	1106.21	0.995	8	1.000	1105.54	0.994	8	1.000	1099.43	0.989	8	1.000
	748.87	7	748.16	0.999	7	1.000	749.64	1.001	7	1.000	747.73	0.998	7	1.000
	1062.27	8	1052.53	0.991	8	1.000	1064.29	1.002	8	1.000	1065.09	1.003	8	1.000
uccase12	0.00%	81491	0.00%	1.000	72235	0.886	0.00%	1.000	72861	0.894	0.00%	1.000	77800	0.955
	0.00%	88801	0.00%	1.000	94285	1.062	0.00%	1.000	62126	0.700	0.00%	1.000	91468	1.030
	0.00%	97614	0.00%	1.000	94512	0.968	0.00%	1.000	88923	0.911	0.00%	1.000	98605	1.010
uccase9	1.74%	633	3.64%	1.000	544	0.859	1.83%	1.000	624	0.986	1.98%	1.000	498	0.787
	6.65%	696	8.63%	1.000	1199	1.723	3.93%	1.000	1418	2.037	1.48%	1.000	1166	1.675
	2.28%	1052	3.69%	1.000	545	0.518	1.50%	1.000	865	0.822	2.82%	1.000	550	0.523
uct-subprob	1544.63	62572	1313.02	**0.850**	47486	**0.759**	1114.60	**0.722**	44339	**0.709**	1102.62	**0.714**	44339	**0.709**
	1948.75	76073	1592.47	**0.817**	60418	**0.794**	1786.03	**0.917**	70090	**0.921**	1631.60	**0.837**	59559	**0.783**
	1870.35	66057	1960.04	1.048	64485	0.976	2367.22	*1.266*	91988	*1.393*	2506.36	*1.340*	95674	*1.448*
unitcal_7	269.85	97	264.17	0.979	89	**0.918**	264.89	0.982	89	**0.918**	272.59	1.010	89	**0.918**
	302.06	225	306.36	1.014	225	1.000	295.28	0.978	176	**0.782**	298.12	0.987	180	**0.800**

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Table A.1: Detailed computational results on MIPLIB 2017 benchmark.

	nolpinf		dualproof				confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	399.99	452	400.05	1.000	452	1.000	384.51	0.961	436	0.965	387.18	0.968	436	0.965
var-smallemery-m6j6	1.00%	567848	0.97%	1.000	562866	0.991	1.04%	1.000	583647	1.028	0.93%	1.000	568323	1.001
	6835.13	744694	0.83%	1.053	645910	0.867	1.05%	1.053	666841	0.895	0.87%	1.053	656232	0.881
	6793.08	692932	0.00%	1.060	753437	1.087	6080.41	**0.895**	668644	0.965	6729.45	0.991	683202	0.986
wachplan	12.50%	244098	0.00%	1.000	249191	1.021	2545.25	**0.354**	240736	0.986	2340.84	**0.325**	219938	**0.901**
	12.50%	213375	0.00%	1.000	205633	0.964	3287.69	**0.457**	297002	*1.392*	3419.67	**0.475**	302179	*1.416*
	12.50%	197319	0.00%	1.000	250301	1.269	2155.54	**0.299**	174423	**0.884**	2343.95	**0.326**	198054	1.004

Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
30n20b8	149.73	171	149.68	1.000	171	1.000	0	0
	622.50	1999	623.60	1.002	1999	1.000	0	0
	693.71	3499	693.56	1.000	3499	1.000	0	0
50v-10	1.32%	822628	1.69%	1.000	829421	1.008	150211	29360749
	1.43%	957507	1.15%	1.000	867997	0.907	175089	32916103
	1.18%	951374	1.37%	1.000	833134	0.876	160740	30814917
CMS750_4	185.83	2028	185.73	0.999	2028	1.000	0	0
	370.78	3254	370.72	1.000	3254	1.000	0	0
	470.44	13518	473.12	1.006	13518	1.000	0	0
academictimetablesmall	∞	2305	∞	1.000	2315	1.004	0	0
	∞	3517	∞	1.000	3505	0.997	0	0
	∞	2681	∞	1.000	2681	1.000	0	0
air05	40.03	648	40.07	1.001	648	1.000	0	0
	36.49	716	36.54	1.001	716	1.000	0	0
	30.27	282	30.22	0.998	282	1.000	0	0
app1-1	3.53	2	3.53	1.000	2	1.000	0	0
	4.89	3	4.94	1.010	3	1.000	0	0
	4.22	6	4.17	0.988	6	1.000	0	0
app1-2	642.51	33	642.80	1.000	33	1.000	0	0
	791.40	20	789.47	0.998	20	1.000	0	0
	620.27	20	618.36	0.997	20	1.000	0	0
assign1-5-8	4.73%	5752207	4.74%	1.000	5736357	0.997	0	0
	4.54%	6817803	4.54%	1.000	6813236	0.999	0	0
	4.79%	6376065	4.80%	1.000	6333262	0.993	0	0
atlanta-ip	3.60%	18583	3.60%	1.000	18533	0.997	184	4764
	3.83%	21126	3.81%	1.000	21153	1.001	239	6541
	4.27%	30903	4.27%	1.000	30903	1.000	282	8068
b1c1s1	17.39%	51191	17.13%	1.000	35962	0.703	3659	2259708
	18.78%	19248	18.36%	1.000	21112	1.097	2327	1474442
	16.14%	18968	17.69%	1.000	18673	0.984	1971	1200355
bab2	1.29%	3460	1.29%	1.000	3473	1.004	0	0
	1.10%	3382	2.44%	1.000	3262	0.965	0	0
	∞	2003	∞	1.000	1981	0.989	0	0
bab6	0.58%	4933	0.58%	1.000	4790	0.971	0	0
	1.14%	3183	1.14%	1.000	3258	1.024	0	0
	1.94%	4744	1.94%	1.000	4779	1.007	0	0
beasleyC3	31.57	83	31.56	1.000	83	1.000	2	323
	17.36	2	17.35	0.999	2	1.000	2	237
	47.26	429	47.20	0.999	453	*1.056*	173	32884
binkar10_1	37.92	2735	31.34	**0.826**	2560	**0.936**	852	689009
	30.65	2389	29.22	0.953	2246	**0.940**	888	717367
	29.69	2264	28.71	0.967	2509	*1.108*	961	775238
blp-ar98	0.27%	237252	0.27%	1.000	238231	1.004	0	0
	0.33%	207970	0.33%	1.000	207500	0.998	0	0
	0.32%	226917	0.32%	1.000	229423	1.011	0	0
blp-ic98	1.38%	308981	1.38%	1.000	304769	0.986	0	0
	2.41%	253422	2.41%	1.000	254061	1.003	0	0
	2.11%	278852	2.11%	1.000	278188	0.998	0	0
bnatt400	970.86	6821	970.91	1.000	6821	1.000	0	0
	1103.87	6346	1105.02	1.001	6346	1.000	0	0
	743.49	5500	745.15	1.002	5500	1.000	0	0
bnatt500	4364.76	29526	4368.17	1.001	29526	1.000	0	0
	6333.70	38962	6333.06	1.000	38962	1.000	0	0
	4967.46	29029	4996.90	1.006	29029	1.000	0	0
bppc4-08	1.92%	797858	1.92%	1.000	797503	1.000	0	0

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
	1.92%	934751	1.92%	1.000	938927	1.004	0	0
	1.92%	791517	1.92%	1.000	793397	1.002	0	0
brazil3	3378.81	2570	3360.46	0.995	2570	1.000	0	0
	4235.60	2347	4252.19	1.004	2347	1.000	0	0
	3799.45	3302	3785.08	0.996	3302	1.000	0	0
buildingenergy	0.13%	96	0.13%	1.000	96	1.000	156	2885535
	0.15%	85	0.15%	1.000	85	1.000	247	4520721
	0.13%	13	0.13%	1.000	12	0.923	0	0
cbs-cta	40.10	1	40.27	1.004	1	1.000	0	0
	313.95	31	314.10	1.000	31	1.000	0	0
	35.69	1	35.77	1.002	1	1.000	0	0
chromaticindex1024-7	33.33%	968	33.33%	1.000	964	0.996	0	0
	33.33%	1176	33.33%	1.000	1171	0.996	0	0
	6469.26	757	6429.72	0.994	757	1.000	0	0
chromaticindex512-7	1180.40	361	1172.37	0.993	361	1.000	0	0
	3704.87	3133	3689.97	0.996	3133	1.000	0	0
	33.33%	40706	33.33%	1.000	40579	0.997	0	0
cmflsp50-24-8-8	4.18%	34634	3.98%	1.000	36090	1.042	2797	23254495
	1.60%	59551	1.99%	1.000	85475	1.435	5780	50843548
	2.08%	51068	4.86%	1.000	37790	0.740	4047	36193400
co-100	1.75%	53846	1.74%	1.000	54008	1.003	0	0
	91.88%	6972	91.77%	1.000	7012	1.006	0	0
	3.23%	10521	3.18%	1.000	10565	1.004	0	0
cod105	47.41%	7367	47.57%	1.000	7261	0.986	0	0
	48.07%	6763	48.00%	1.000	6829	1.010	0	0
	48.07%	6601	48.07%	1.000	6601	1.000	0	0
comp07-2idx	966.67%	4003	966.67%	1.000	3996	0.998	0	0
	2800.00%	747	2800.00%	1.000	743	0.995	0	0
	1716.67%	1416	1716.67%	1.000	1449	1.023	0	0
comp21-2idx	247.43%	10926	247.43%	1.000	10931	1.000	0	0
	195.50%	9843	195.50%	1.000	9835	0.999	0	0
	248.72%	11698	248.72%	1.000	11711	1.001	0	0
cost266-UUE	6047.83	463222	4923.15	**0.814**	375684	**0.811**	21812	44508041
	4081.74	333136	3728.83	**0.914**	294630	**0.884**	21176	42865500
	5401.04	414623	4067.72	**0.753**	306702	**0.740**	20643	41905352
cryptanalysiskb128n5obj14	∞	110	∞	1.000	110	1.000	0	0
	∞	59	∞	1.000	59	1.000	0	0
	∞	91	∞	1.000	90	0.989	0	0
cryptanalysiskb128n5obj16	∞	104	∞	1.000	104	1.000	0	0
	2798.71	37	2790.65	0.997	37	1.000	0	0
	∞	97	∞	1.000	97	1.000	0	0
csched007	2327.45	187288	2327.77	1.000	187288	1.000	0	0
	2618.01	220934	2613.95	0.998	220934	1.000	0	0
	3392.15	247755	3393.08	1.000	247755	1.000	0	0
csched008	2.81%	456376	2.81%	1.000	455870	0.999	0	0
	2.33%	690662	2.33%	1.000	694455	1.005	0	0
	5758.73	546382	5772.95	1.002	546382	1.000	0	0
cvs16r128-89	23.28%	67922	23.28%	1.000	67980	1.001	0	0
	22.61%	34961	22.61%	1.000	34973	1.000	0	0
	23.00%	47504	23.01%	1.000	47219	0.994	0	0
dano3_3	144.71	12	143.70	0.993	10	**0.833**	10	92385
	142.99	12	142.65	0.998	14	*1.167*	8	72422
	124.91	17	124.56	0.997	17	1.000	8	77472
dano3_5	638.53	276	635.04	0.995	276	1.000	171	1651798
	286.66	166	285.81	0.997	159	0.958	141	1364112
	287.06	140	285.94	0.996	140	1.000	55	532225

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
decomp2	2.45	1	2.39	0.976	1	1.000	0	0
	2.42	1	2.42	1.000	1	1.000	0	0
	2.46	1	2.50	1.016	1	1.000	0	0
drayage-100-23	16.51	32	16.43	0.995	32	1.000	0	0
	19.54	48	19.52	0.999	48	1.000	0	0
	13.52	16	13.50	0.999	16	1.000	0	0
drayage-25-23	0.07%	774368	0.07%	1.000	720814	0.931	13184	17492
	0.07%	791377	0.07%	1.000	790871	0.999	32335	46243
	6981.60	552534	6941.84	0.994	552534	1.000	16072	21359
dws008-01	44.26%	137675	44.84%	1.000	144766	1.052	5558	15334528
	48.22%	151938	44.28%	1.000	157395	1.036	6508	18130986
	57.03%	150243	52.63%	1.000	153108	1.019	6985	19693643
eil33-2	80.75	343	81.20	1.006	343	1.000	0	0
	104.17	395	101.92	0.978	395	1.000	0	0
	105.69	541	105.72	1.000	541	1.000	0	0
eilA101-2	20.05%	11127	20.05%	1.000	11110	0.998	0	0
	13.19%	12812	13.20%	1.000	12688	0.990	0	0
	13.37%	13480	13.37%	1.000	13480	1.000	0	0
enlight_hard	0.50	1	0.50	1.000	1	1.000	0	0
	0.50	1	0.50	1.000	1	1.000	0	0
	0.50	1	0.50	1.000	1	1.000	0	0
ex10	493.40	1	493.80	1.001	1	1.000	0	0
	495.40	1	497.94	1.005	1	1.000	0	0
	581.58	1	581.12	0.999	1	1.000	0	0
ex9	29.02	1	27.98	0.964	1	1.000	0	0
	27.64	1	27.30	0.988	1	1.000	0	0
	27.67	1	27.02	0.977	1	1.000	0	0
exp-1-500-5-5	2.31	1	2.28	0.987	1	1.000	1	730
	2.22	1	2.22	1.000	1	1.000	1	730
	2.23	1	2.21	0.991	1	1.000	1	730
fast0507	323.39	1284	322.23	0.996	1284	1.000	0	0
	281.71	1223	280.17	0.995	1223	1.000	0	0
	366.66	1711	365.44	0.997	1711	1.000	0	0
fastxgemm-n2r6s0t2	5456.64	1254092	4702.82	**0.862**	1118937	**0.892**	30827	696948
	2297.35	544145	4017.11	*1.749*	1012967	*1.862*	23016	435688
	2695.76	647594	3129.08	*1.161*	769500	*1.188*	15845	348392
fhnw-binpack4-48	∞	4024296	∞	1.000	4040499	1.004	0	0
	∞	3523510	∞	1.000	3525851	1.001	0	0
	∞	3420581	∞	1.000	3413924	0.998	0	0
fhnw-binpack4-4	∞	14776290	∞	1.000	14733968	0.997	0	0
	∞	14011682	∞	1.000	13981261	0.998	0	0
	∞	11641609	∞	1.000	11607995	0.997	0	0
fiball	465.46	4111	465.55	1.000	4111	1.000	0	0
	447.05	3521	447.14	1.000	3521	1.000	0	0
	500.06	5672	499.03	0.998	5672	1.000	0	0
gen-ip002	1308.28	5856334	1315.68	1.006	5856334	1.000	0	0
	1302.36	5478569	1295.56	0.995	5478569	1.000	0	0
	1273.67	5583912	1271.92	0.999	5583912	1.000	0	0
gen-ip054	3074.29	15245360	3047.64	0.991	15245360	1.000	0	0
	2534.26	12476019	2530.93	0.999	12476019	1.000	0	0
	3399.83	16438070	3381.24	0.995	16438070	1.000	0	0
germanrr	1.46%	3402	1.46%	1.000	3418	1.005	0	0
	2.11%	2852	2.11%	1.000	2851	1.000	0	0
	1.94%	3551	1.94%	1.000	3559	1.002	0	0
gfd-schedulen180f7d50m30k18	∞	4	∞	1.000	4	1.000	0	0
	∞	8	∞	1.000	8	1.000	0	0

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
	∞	10	∞	1.000	10	1.000	0	0
glass-sc	2667.24	241329	2655.26	0.996	241329	1.000	0	0
	3235.22	289206	3214.67	0.994	289206	1.000	0	0
	2823.90	251112	2819.06	0.998	251112	1.000	0	0
glass4	4015.23	2705421	4008.75	0.998	2705421	1.000	1	2
	2392.08	1888717	2392.84	1.000	1888717	1.000	6	8
	2194.83	1599046	2212.84	1.008	1599046	1.000	1	2
gmu-35-40	0.04%	2422160	0.05%	1.000	2051936	0.847	1246	1692
	0.04%	1978991	0.03%	1.000	2099939	1.061	1680	2631
	0.04%	1863551	0.03%	1.000	1381092	0.741	1375	1556
gmu-35-50	0.02%	1321065	0.02%	1.000	1317781	0.998	160	161
	0.03%	1165732	0.03%	1.000	1247342	1.070	1179	1824
	0.02%	1445028	0.04%	1.000	1016723	0.704	2200	5603
graph20-20-1rand	163.83%	6109	163.73%	1.000	6171	1.010	0	0
	165.38%	8286	165.38%	1.000	8277	0.999	0	0
	172.66%	7506	172.66%	1.000	7513	1.001	0	0
graphdraw-domain	1031.77	1757494	1010.47	0.979	1823083	1.037	35	44
	1145.40	1975394	1122.85	0.980	1941578	0.983	49	74
	1601.52	3104489	1664.67	1.039	2907888	**0.937**	52	78
h80x6320d	75.72	5	69.54	**0.918**	4	**0.800**	5	13270
	85.29	6	86.17	1.010	10	*1.667*	34	15863
	85.29	5	86.62	1.016	5	1.000	15	14111
highschool1-aigio	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
hypothyroid-k1	20.15	1	20.04	0.995	1	1.000	0	0
	19.95	1	19.99	1.002	1	1.000	0	0
	19.94	1	20.16	1.011	1	1.000	0	0
ic97_potential	0.84%	7215487	0.84%	1.000	7214792	1.000	3	3
	0.75%	6122912	0.75%	1.000	6107856	0.998	6	6
	0.86%	7594910	0.86%	1.000	7579116	0.998	34	34
icir97_tension	6501.51	2533775	0.07%	1.107	3185773	1.257	56411	3418436
	0.07%	3124196	0.05%	1.000	2776552	0.889	87256	5105602
	0.11%	2953553	0.08%	1.000	2729235	0.924	56505	3299716
irish-electricity	∞	93	∞	1.000	93	1.000	0	0
	27.01%	1364	18.43%	1.000	1317	0.966	43	598444
	∞	1333	∞	1.000	1333	1.000	5	69831
irp	12.37	6	12.51	1.011	6	1.000	0	0
	12.01	4	12.05	1.003	4	1.000	0	0
	12.52	5	12.58	1.005	5	1.000	0	0
istanbul-no-cutoff	152.91	347	154.02	1.007	347	1.000	0	0
	166.08	245	166.34	1.002	245	1.000	0	0
	285.94	475	285.14	0.997	475	1.000	0	0
k1mushroom	1890.02	7	1897.56	1.004	7	1.000	0	0
	1550.04	11	1583.93	1.022	11	1.000	0	0
	1298.16	3	1321.29	1.018	3	1.000	0	0
lectsched-5-obj	166.67%	148759	166.67%	1.000	148725	1.000	0	0
	120.00%	129616	120.00%	1.000	130812	1.009	0	0
	126.67%	64823	126.67%	1.000	64923	1.002	0	0
leo1	6.11%	80401	6.11%	1.000	80819	1.005	0	0
	7.14%	34819	7.14%	1.000	34905	1.002	0	0
	7.53%	46085	7.53%	1.000	45969	0.997	0	0
leo2	∞	101572	∞	1.000	101616	1.000	0	0
	∞	110430	∞	1.000	110967	1.005	0	0
	∞	146894	∞	1.000	146706	0.999	0	0
lotsize	0.65%	12057	0.67%	1.000	16786	1.392	9904	1427070

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
	0.81%	50851	0.88%	1.000	20493	0.403	13067	2090525
	0.57%	17809	0.70%	1.000	17911	1.006	9579	1783889
mad	∞	13353509	∞	1.000	8295624	0.621	149479	405608
	∞	17989284	∞	1.000	14934806	0.830	160629	565760
	∞	19538859	∞	1.000	15381075	0.787	117222	324400
map10	1004.30	1637	1006.71	1.002	1637	1.000	0	0
	631.41	724	633.84	1.004	724	1.000	0	0
	791.27	965	792.96	1.002	965	1.000	0	0
map16715-04	2160.58	1933	2158.43	0.999	1933	1.000	0	0
	2333.35	2173	2335.51	1.001	2173	1.000	0	0
	2160.02	1990	2160.04	1.000	1990	1.000	0	0
markshare2	∞	5818260	∞	1.000	5827069	1.002	0	0
	∞	5581862	∞	1.000	5581862	1.000	0	0
	∞	5053235	∞	1.000	5052479	1.000	0	0
markshare_4_0	72.10	612396	72.47	1.005	612396	1.000	0	0
	69.61	589762	70.48	1.012	589762	1.000	0	0
	85.86	719508	85.88	1.000	719508	1.000	0	0
mas74	1680.77	4932223	1680.79	1.000	4932223	1.000	92873	92873
	2286.80	7992914	2282.09	0.998	7992914	1.000	128510	128510
	1567.75	4674399	1563.59	0.997	4674399	1.000	98609	98609
mas76	137.46	406104	136.88	0.996	406104	1.000	13938	13938
	168.12	525538	168.46	1.002	525538	1.000	17151	17151
	150.22	450422	152.65	1.016	450422	1.000	14151	14151
mc11	167.73	8168	149.40	**0.891**	6484	**0.794**	2127	614288
	93.83	2482	80.39	**0.857**	1411	**0.568**	654	188259
	94.12	2184	106.11	*1.127*	3386	*1.550*	1370	385646
mcsched	317.83	11378	318.21	1.001	11378	1.000	0	0
	236.22	9846	235.33	0.996	9846	1.000	0	0
	306.93	12017	306.32	0.998	12017	1.000	0	0
mik-250-20-75-4	52.87	23893	52.78	0.998	23893	1.000	3977	50814
	43.87	15175	43.96	1.002	15175	1.000	2127	29061
	52.23	20733	52.36	1.002	20733	1.000	3807	48155
milo-v12-6-r2-40-1	8.30%	246695	9.47%	1.000	189681	0.769	18301	249990
	9.82%	263755	8.96%	1.000	323326	1.226	27361	379491
	10.19%	266711	11.33%	1.000	417232	1.564	24366	268084
momentum1	8.58%	100459	24.76%	1.000	94037	0.936	2000	672700
	7.63%	207739	7.36%	1.000	91471	0.440	2000	632676
	6.30%	127751	6.53%	1.000	188055	1.472	2203	722065
mushroom-best	616.01	30449	579.50	**0.941**	27393	**0.900**	2015	82418
	134.13%	94486	134.09%	1.000	94624	1.001	5944	75253
	122.03%	98065	121.97%	1.000	98893	1.008	8436	98461
mzzv11	210.49	484	210.71	1.001	484	1.000	0	0
	262.63	987	263.08	1.002	987	1.000	0	0
	196.57	616	195.89	0.997	616	1.000	0	0
mzzv42z	175.32	415	175.26	1.000	415	1.000	0	0
	243.58	712	246.00	1.010	712	1.000	0	0
	306.93	719	306.34	0.998	719	1.000	0	0
n2seq36q	927.69	5438	936.81	1.010	5438	1.000	0	0
	1061.23	4712	1061.28	1.000	4712	1.000	0	0
	1169.86	4632	1170.79	1.001	4632	1.000	0	0
n3div36	2.58%	218772	2.59%	1.000	213866	0.978	0	0
	2.86%	207276	2.86%	1.000	207136	0.999	0	0
	2.68%	205006	2.69%	1.000	202891	0.990	0	0
n5-3	28.03	1124	26.40	**0.942**	926	**0.824**	108	100504
	29.00	959	27.79	0.958	971	1.013	203	191466
	29.06	1213	27.09	**0.932**	1087	**0.896**	96	91628

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
neos-1122047	10.00	1	9.92	0.992	1	1.000	0	0
	9.79	1	9.76	0.997	1	1.000	0	0
	9.81	1	9.70	0.989	1	1.000	0	0
neos-1171448	57.80	101	58.11	1.005	101	1.000	2	21
	5.15	1	5.16	1.002	1	1.000	2	23
	51.31	86	51.55	1.005	86	1.000	2	22
neos-1171737	1.04%	3912	1.04%	1.000	3912	1.000	69	4277
	1.56%	3999	1.56%	1.000	4009	1.003	58	3353
	1.04%	11889	1.30%	1.000	11719	0.986	306	23789
neos-1354092	∞	613	∞	1.000	613	1.000	0	0
	∞	830	∞	1.000	820	0.988	0	0
	∞	639	∞	1.000	639	1.000	0	0
neos-1445765	43.75	133	43.72	0.999	133	1.000	0	0
	44.26	141	44.19	0.998	141	1.000	0	0
	44.82	125	44.74	0.998	125	1.000	0	0
neos-1456979	7.49%	40037	7.49%	1.000	39961	0.998	2070	3273
	6.84%	38580	6.84%	1.000	38750	1.004	1659	2480
	7.31%	31436	7.29%	1.000	31540	1.003	1598	2633
neos-1582420	21.78	18	21.85	1.003	18	1.000	0	0
	10.89	9	10.92	1.003	9	1.000	0	0
	55.11	1381	55.49	1.007	1381	1.000	0	0
neos-2075418-temuka	6997.21	1	7024.05	1.004	1	1.000	0	0
	4532.11	1	4517.94	0.997	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-2657525-crna	∞	3044031	∞	1.000	3064132	1.007	0	0
	∞	3690202	∞	1.000	3681104	0.998	0	0
	∞	2110438	∞	1.000	2122332	1.006	0	0
neos-2746589-doon	0.47%	54070	0.46%	1.000	55681	1.030	0	0
	0.73%	30207	0.73%	1.000	30280	1.002	0	0
	0.11%	183194	0.11%	1.000	182349	0.995	0	0
neos-2978193-inde	0.50%	542072	0.50%	1.000	549249	1.013	17897	273210178
	0.13%	567306	0.13%	1.000	573707	1.011	17835	272478661
	0.50%	536991	0.50%	1.000	548119	1.021	21148	323366127
neos-2987310-joes	17.79	1	17.49	0.983	1	1.000	1	52
	15.29	1	15.31	1.001	1	1.000	1	42
	13.87	1	13.67	0.986	1	1.000	1	42
neos-3004026-krka	53.08	2711	53.06	1.000	2711	1.000	0	0
	61.96	3485	62.47	1.008	3485	1.000	0	0
	46.48	1764	46.28	0.996	1764	1.000	0	0
neos-3024952-loue	4646.63	383076	4646.86	1.000	383076	1.000	0	0
	0.07%	687963	0.07%	1.000	688312	1.001	0	0
	0.05%	1106581	0.04%	1.000	1114650	1.007	0	0
neos-3046615-murg	169.81%	6970717	169.81%	1.000	6971706	1.000	0	0
	166.11%	6369831	166.11%	1.000	6364063	0.999	0	0
	163.72%	7603729	163.66%	1.000	7613539	1.001	0	0
neos-3083819-nubu	12.75	2020	12.72	0.998	2020	1.000	0	0
	12.42	1578	12.37	0.996	1578	1.000	0	0
	20.73	3812	20.79	1.003	3812	1.000	0	0
neos-3216931-puriri	116.41%	5521	116.41%	1.000	5546	1.005	0	0
	7159.50	9731	5.50%	1.006	9705	0.997	0	0
	147.13%	4812	147.13%	1.000	4790	0.995	0	0
neos-3381206-awhea	1.19	1	1.18	0.992	1	1.000	0	0
	1.20	1	1.21	1.008	1	1.000	0	0
	1.24	1	1.20	0.968	1	1.000	0	0
neos-3402294-bobin	3065.94	16574	4386.37	*1.431*	40294	*2.431*	644	1394
	1633.59	11810	618.95	**0.379**	3428	**0.290**	29	96

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
	2712.34	22655	1620.92	**0.598**	9242	**0.408**	179	382
neos-3402454-bohle	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-3555904-turama	18.01%	146	18.01%	1.000	145	0.993	0	0
	∞	18	∞	1.000	18	1.000	0	0
	18.01%	16934	18.01%	1.000	16797	0.992	0	0
neos-3627168-kasai	0.10%	4724171	0.15%	1.000	4555684	0.964	249389	15427453
	0.07%	5205816	0.09%	1.000	4132791	0.794	129233	8161046
	0.07%	4925938	0.27%	1.000	5147129	1.045	198826	16328781
neos-3656078-kumeu	∞	32	∞	1.000	32	1.000	0	0
	∞	82	∞	1.000	82	1.000	0	0
	∞	122	∞	1.000	122	1.000	0	0
neos-3754480-nidda	∞	19992472	∞	1.000	20000763	1.000	445975	50463522
	∞	18587877	∞	1.000	18439214	0.992	421595	42225596
	∞	18152036	∞	1.000	19108471	1.053	364389	41023048
neos-3988577-wolgan	∞	310	∞	1.000	312	1.006	0	0
	∞	179	∞	1.000	179	1.000	0	0
	∞	439	∞	1.000	439	1.000	0	0
neos-4300652-rahue	431.97%	1366	431.97%	1.000	1365	0.999	639	3103
	813.20%	1205	809.48%	1.000	1213	1.007	478	2320
	316.83%	2125	316.83%	1.000	2127	1.001	718	2424
neos-4338804-snowy	1.66%	4865547	1.66%	1.000	4875741	1.002	0	0
	0.82%	6730558	0.82%	1.000	6738902	1.001	0	0
	1.66%	5069364	1.66%	1.000	5067404	1.000	0	0
neos-4387871-tavua	11.46%	114951	11.39%	1.000	118375	1.030	6667	6579165
	14.12%	116934	14.13%	1.000	116171	0.993	7571	7450182
	18.68%	96140	18.66%	1.000	96695	1.006	6492	6305428
neos-4413714-turia	296.85	2	299.23	1.008	2	1.000	1	1
	403.95	2	404.80	1.002	2	1.000	1	1
	285.79	2	277.10	0.970	2	1.000	0	0
neos-4532248-waihi	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-4647030-tutaki	0.01%	24399	0.01%	1.000	24413	1.001	18	13495
	0.01%	22843	0.01%	1.000	22893	1.002	20	15460
	0.01%	27221	0.01%	1.000	27292	1.003	34	28007
neos-4722843-widden	2640.30	11357	2651.33	1.004	11357	1.000	0	0
	1022.28	3376	1033.65	1.011	3376	1.000	0	0
	1715.11	7919	1714.52	1.000	7919	1.000	0	0
neos-4738912-atrato	811.47	61981	813.40	1.002	61981	1.000	0	0
	3825.61	324992	3808.90	0.996	324992	1.000	0	0
	916.83	95736	914.39	0.997	95736	1.000	0	0
neos-4763324-toguru	46.04%	8436	46.04%	1.000	8436	1.000	0	0
	45.08%	14960	45.08%	1.000	14962	1.000	0	0
	48.94%	7145	48.94%	1.000	7145	1.000	0	0
neos-4954672-berkel	8.81%	1012935	8.48%	1.000	1019990	1.007	105716	11413161
	8.69%	798448	8.71%	1.000	819107	1.026	100039	11144234
	7.63%	870007	8.00%	1.000	891993	1.025	112504	12275201
neos-5049753-cuanza	∞	52	∞	1.000	52	1.000	0	0
	15.39%	14	15.39%	1.000	14	1.000	0	0
	15.20%	12	15.20%	1.000	12	1.000	0	0
neos-5052403-cygnet	1.60%	113	1.60%	1.000	113	1.000	0	0
	1.38%	1	1.38%	1.000	1	1.000	0	0
	1.19%	63	1.19%	1.000	63	1.000	0	0
neos-5093327-huahum	10.34%	52594	10.32%	1.000	49854	0.948	4579	51311347

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
	10.74%	52498	10.43%	1.000	52521	1.000	4942	55271261
	12.17%	51549	12.17%	1.000	48532	0.941	5145	57673811
neos-5104907-jarama	∞	8	∞	1.000	8	1.000	0	0
	∞	9	∞	1.000	9	1.000	0	0
	∞	4	∞	1.000	4	1.000	0	0
neos-5107597-kakapo	2138.51	560533	2144.47	1.003	560533	1.000	0	0
	1724.48	472393	1725.41	1.001	472393	1.000	0	0
	5915.74	1725439	5927.88	1.002	1725439	1.000	0	0
neos-5114902-kasavu	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-5188808-nattai	1223.97	11765	1251.29	1.022	12145	1.032	311	279857
	1257.42	13094	1292.07	1.028	13554	1.035	417	373585
	1341.10	12634	1380.62	1.029	12548	0.993	413	374195
neos-5195221-niemur	2827.57	47466	2813.87	0.995	47466	1.000	0	0
	2906.16	25010	2911.85	1.002	25010	1.000	0	0
	2885.99	33779	2890.78	1.002	33779	1.000	0	0
neos-631710	14.21%	2	14.21%	1.000	2	1.000	0	0
	8.90%	4	8.90%	1.000	4	1.000	0	0
	14.21%	3	14.21%	1.000	3	1.000	0	0
neos-662469	0.01%	59651	0.01%	1.000	59651	1.000	0	0
	0.00%	50515	0.00%	1.000	50627	1.002	0	0
	0.01%	57704	0.01%	1.000	56995	0.988	0	0
neos-787933	1.38	1	1.37	0.993	1	1.000	0	0
	1.40	1	1.39	0.993	1	1.000	0	0
	1.35	1	1.41	1.044	1	1.000	0	0
neos-827175	6.16	1	6.10	0.990	1	1.000	0	0
	8.14	1	8.21	1.009	1	1.000	0	0
	10.21	1	10.23	1.002	1	1.000	0	0
neos-848589	32.15%	247	32.15%	1.000	256	1.036	26	11963526
	42.57%	151	42.95%	1.000	148	0.980	1	464090
	46.27%	106	46.27%	1.000	106	1.000	17	7822005
neos-860300	17.20	2	17.27	1.004	2	1.000	0	0
	13.31	2	13.35	1.003	2	1.000	0	0
	23.08	3	23.18	1.004	3	1.000	0	0
neos-873061	9.28%	159	9.28%	1.000	155	0.975	17	562652
	7.72%	148	7.72%	1.000	148	1.000	5	171769
	8.12%	168	8.12%	1.000	168	1.000	6	189338
neos-911970	1.05%	1400846	1.05%	1.000	1400854	1.000	907	976
	3.01%	1931001	2.49%	1.000	1814127	0.939	171	211
	0.04%	10359753	0.06%	1.000	11460910	1.106	97138	97261
neos-933966	1374.27	138	1374.28	1.000	138	1.000	0	0
	846.61	38	848.27	1.002	38	1.000	0	0
	2186.79	283	2180.73	0.997	283	1.000	0	0
neos-950242	100.00%	9312	100.00%	1.000	9288	0.997	0	0
	100.00%	8505	100.00%	1.000	8446	0.993	0	0
	100.00%	15629	100.00%	1.000	15629	1.000	0	0
neos-957323	86.10	2	86.06	1.000	2	1.000	0	0
	110.81	5	110.59	0.998	5	1.000	0	0
	79.78	2	80.10	1.004	2	1.000	0	0
neos-960392	879.21	15	881.09	1.002	15	1.000	0	0
	1447.09	102	1439.63	0.995	102	1.000	0	0
	1364.81	403	1363.87	0.999	403	1.000	0	0
neos17	14.58	10185	25.95	*1.780*	22460	*2.205*	2747	155764
	10.20	6549	9.39	**0.921**	5644	**0.862**	359	19702
	7.67	4115	9.84	*1.283*	6376	*1.549*	601	34787

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
neos5	985.69	3170813	1007.54	1.022	3292114	1.038	51655	154941
	1960.29	6799306	1234.24	**0.630**	4202380	**0.618**	62208	178075
	1431.38	4934304	1183.51	**0.827**	4100005	**0.831**	56177	163393
neos859080	0.52	792	0.50	0.962	792	1.000	0	0
	0.53	655	0.54	1.019	655	1.000	0	0
	0.52	565	0.55	*1.058*	565	1.000	0	0
neos8	1.95	1	1.95	1.000	1	1.000	0	0
	1.84	1	1.89	1.027	1	1.000	0	0
	1.81	1	1.83	1.011	1	1.000	0	0
net12	1838.09	1211	1842.42	1.002	1211	1.000	0	0
	1627.97	1816	1631.28	1.002	1816	1.000	0	0
	1557.45	1695	1561.43	1.003	1695	1.000	0	0
netdiversion	846.23	43	848.00	1.002	43	1.000	0	0
	2381.00	88	2364.82	0.993	88	1.000	0	0
	1086.46	27	1087.12	1.001	27	1.000	0	0
nexp-150-20-8-5	5904.05	10910	3539.59	**0.600**	5786	**0.530**	14898	15639667
	1.20%	20440	3635.13	**0.505**	7166	**0.351**	7298	7952684
	2297.43	2837	0.83%	3.134	13054	4.601	5620	6163405
ns1116954	∞	32	∞	1.000	32	1.000	0	0
	∞	57	∞	1.000	57	1.000	0	0
	∞	75	∞	1.000	75	1.000	0	0
ns1208400	417.80	2004	419.49	1.004	2004	1.000	0	0
	680.25	2339	683.06	1.004	2339	1.000	0	0
	1074.25	2315	1074.09	1.000	2315	1.000	0	0
ns1644855	7.37%	36	7.37%	1.000	36	1.000	0	0
	7.37%	79	7.37%	1.000	79	1.000	0	0
	964.29	1	974.47	1.011	1	1.000	0	0
ns1760995	58.41%	1	58.41%	1.000	1	1.000	0	0
	71.46%	1	71.46%	1.000	1	1.000	0	0
	49.34%	1	48.93%	1.000	1	1.000	0	0
ns1830653	287.87	14558	287.45	0.999	14558	1.000	0	0
	133.15	7527	134.33	1.009	7527	1.000	0	0
	147.56	7267	148.24	1.005	7267	1.000	0	0
ns1952667	∞	52524	∞	1.000	52208	0.994	0	0
	1404.32	9508	1392.38	0.991	9508	1.000	0	0
	968.78	4900	968.90	1.000	4900	1.000	0	0
nu25-pr12	5.30	53	5.36	1.011	53	1.000	0	0
	6.04	66	6.11	1.012	66	1.000	0	0
	6.02	16	6.05	1.005	16	1.000	0	0
nursesched-medium-hint03	1657.78%	1113	1657.78%	1.000	1100	0.988	0	0
	3021.25%	2062	3021.25%	1.000	2050	0.994	0	0
	1077.84%	1121	1077.84%	1.000	1121	1.000	0	0
nursesched-sprint02	140.68	370	142.08	1.010	370	1.000	0	0
	85.08	409	85.18	1.001	409	1.000	0	0
	67.68	222	67.71	1.000	222	1.000	0	0
nw04	38.05	6	37.93	0.997	6	1.000	0	0
	31.40	5	31.39	1.000	5	1.000	0	0
	35.20	6	35.16	0.999	6	1.000	0	0
opm2-z10-s4	24.70%	1010	24.70%	1.000	1000	0.990	0	0
	27.76%	580	27.76%	1.000	586	1.010	0	0
	26.96%	1011	26.96%	1.000	1015	1.004	0	0
p200x1188c	3.51	2	3.53	1.006	2	1.000	0	0
	4.76	2	3.96	**0.832**	3	*1.500*	3	1249
	3.62	2	3.62	1.000	2	1.000	0	0
peg-solitaire-a3	∞	5760	∞	1.000	5752	0.999	0	0
	∞	3566	∞	1.000	3557	0.997	0	0

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
	∞	3965	∞	1.000	3969	1.001	0	0
pg5_34	1260.38	149366	1173.22	**0.931**	148717	0.996	12176	12548686
	1334.91	170764	1134.07	**0.850**	144543	**0.846**	17535	19386420
	1266.61	151919	1085.15	**0.857**	121673	**0.801**	18696	21243804
pg	113.10	3604	101.85	**0.901**	2687	**0.746**	475	531333
	88.16	1065	86.23	0.978	1372	*1.288*	421	506326
	74.36	1291	107.44	*1.445*	2311	*1.790*	768	922690
physicliansched3-3	∞	417	∞	1.000	415	0.995	0	0
	∞	313	∞	1.000	313	1.000	0	0
	∞	363	∞	1.000	361	0.994	0	0
physicliansched6-2	124.74	377	124.81	1.001	377	1.000	1	102
	465.63	2804	462.02	0.992	2804	1.000	0	0
	44.54	1	44.74	1.004	1	1.000	0	0
piperout-08	791.24	130	797.03	1.007	130	1.000	0	0
	617.51	552	606.54	0.982	552	1.000	0	0
	914.01	596	923.85	1.011	596	1.000	0	0
piperout-27	140.40	2	140.11	0.998	2	1.000	0	0
	276.77	566	275.91	0.997	566	1.000	0	0
	331.44	72	332.32	1.003	72	1.000	0	0
pk1	111.14	304863	107.55	0.968	301100	0.988	9412	103204
	109.43	324617	109.16	0.998	317026	0.977	10622	130403
	115.59	331290	112.34	0.972	328715	0.992	8973	95646
proteindesign121hz512p9	9.60%	579	9.60%	1.000	591	1.021	0	0
	7.94%	432	7.94%	1.000	440	1.019	0	0
	26.01%	602	26.02%	1.000	593	0.985	0	0
proteindesign122trx11p8	1.95%	3	1.95%	1.000	3	1.000	0	0
	1.91%	8	1.91%	1.000	8	1.000	0	0
	1.93%	17	1.93%	1.000	17	1.000	0	0
qap10	87.95	3	87.99	1.000	3	1.000	0	0
	112.11	5	111.82	0.997	5	1.000	0	0
	198.19	15	197.87	0.998	15	1.000	0	0
radiationm18-12-05	12.99%	478942	12.99%	1.000	479812	1.002	0	0
	0.05%	756043	0.05%	1.000	750150	0.992	0	0
	1.89%	551002	1.89%	1.000	551080	1.000	0	0
radiationm40-10-02	67.02%	51902	67.02%	1.000	53316	1.027	0	0
	57.74%	26807	57.74%	1.000	27109	1.011	0	0
	22.69%	98555	22.69%	1.000	99008	1.005	0	0
rail01	2.74%	201	2.74%	1.000	200	0.995	0	0
	25.21%	183	25.21%	1.000	182	0.995	0	0
	7.32%	178	7.32%	1.000	183	1.028	0	0
rail02	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
rail507	157.47	623	156.67	0.995	623	1.000	0	0
	178.99	783	180.04	1.006	783	1.000	0	0
	193.76	771	193.43	0.998	771	1.000	0	0
ran14x18-disj-8	1646.55	581323	2109.62	*1.281*	656920	*1.130*	40771	4211033
	1325.91	421619	1785.31	*1.346*	564900	*1.340*	40555	4129085
	1620.56	585345	1694.59	1.046	593570	1.014	39060	3993649
rd-rplusc-21	≥ 10000%	457613	≥ 10000%	1.000	484631	1.059	277	354
	≥ ≥ 10000%	688442	≥ 10000%	1.000	737139	1.071	162	165
	≥ 10000%	606726	≥ 10000%	1.000	763715	1.259	117	117
reblock115	4402.19	704168	4390.48	0.997	704168	1.000	0	0
	6584.39	882785	6605.46	1.003	882785	1.000	0	0
	5885.72	832788	5894.68	1.002	832788	1.000	0	0
rmatr100-p10	168.13	809	166.48	0.990	809	1.000	900	4785858

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
	164.49	822	162.84	0.990	822	1.000	927	4920613
	160.06	783	160.62	1.003	827	*1.056*	719	3828632
rmatr200-p5	22.40%	423	22.40%	1.000	421	0.995	247	5912115
	19.56%	427	19.56%	1.000	423	0.991	200	4772878
	21.08%	392	21.08%	1.000	403	1.028	331	7867800
rocI-4-11	637.01	12970	638.21	1.002	12970	1.000	0	0
	1001.58	17602	1001.80	1.000	17602	1.000	0	0
	499.15	9550	498.07	0.998	9550	1.000	0	0
rocII-5-11	108.38%	3526	108.52%	1.000	3399	0.964	72	1539
	109.24%	2882	109.87%	1.000	2764	0.959	78	1994
	109.11%	2527	109.11%	1.000	2522	0.998	67	1983
rococoB10-011000	13.69%	151842	13.71%	1.000	151103	0.995	0	0
	15.11%	142431	15.09%	1.000	143253	1.006	0	0
	12.79%	154266	12.80%	1.000	153839	0.997	0	0
rococoC10-001000	766.88	53303	765.76	0.999	53303	1.000	0	0
	850.38	63090	851.99	1.002	63090	1.000	0	0
	1631.18	162527	1626.91	0.997	162527	1.000	0	0
roi2alpha3n4	1556.68	14465	1424.80	**0.915**	12529	**0.866**	6050	15069
	1940.55	17446	1940.46	1.000	17446	1.000	1160	2162
	1490.30	13303	1486.54	0.997	13303	1.000	656	1508
roi5alpha10n8	35.35%	6064	35.37%	1.000	5989	0.988	4891	20517
	38.11%	6792	40.36%	1.000	6346	0.934	4223	16719
	32.14%	6775	32.14%	1.000	6789	1.002	5672	34410
roll3000	36.98	1986	36.86	0.997	1986	1.000	190	204
	39.08	2149	38.91	0.996	2149	1.000	97	100
	57.27	3491	60.26	*1.052*	3736	*1.070*	234	255
s100	5.53%	20	5.53%	1.000	20	1.000	0	0
	29.84%	17	29.84%	1.000	17	1.000	0	0
	1.06%	22	1.06%	1.000	22	1.000	0	0
s250r10	0.28%	22905	0.28%	1.000	22897	1.000	0	0
	6373.62	45426	6366.45	0.999	45426	1.000	0	0
	0.23%	31617	0.23%	1.000	31811	1.006	0	0
satellites2-40	∞	19	∞	1.000	19	1.000	0	0
	∞	4	∞	1.000	4	1.000	0	0
	70.59%	33	70.59%	1.000	33	1.000	0	0
satellites2-60-fs	∞	33	∞	1.000	33	1.000	0	0
	∞	137	∞	1.000	137	1.000	0	0
	∞	28	∞	1.000	28	1.000	0	0
savsched1	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
sct2	0.05%	629842	0.03%	1.000	600226	0.953	26218	17933421
	0.03%	978502	0.05%	1.000	659682	0.674	20691	15761940
	0.03%	1085466	0.03%	1.000	994927	0.917	20090	14101828
seymour1	70.11	1234	90.45	*1.290*	1627	*1.318*	101	12890
	66.75	1474	67.90	1.017	1466	0.995	98	12630
	72.97	1811	72.05	0.987	1822	1.006	112	14950
seymour	0.66%	242716	0.66%	1.000	242500	0.999	0	0
	0.68%	221477	0.68%	1.000	222209	1.003	0	0
	0.74%	225445	0.74%	1.000	225373	1.000	0	0
sing326	0.15%	9102	0.15%	1.000	11755	1.291	523	4451567
	0.17%	8193	0.17%	1.000	8196	1.000	432	3687168
	0.32%	7833	0.32%	1.000	7997	1.021	853	7436397
sing44	0.45%	5559	0.45%	1.000	5531	0.995	249	2726406
	0.19%	7342	0.19%	1.000	7349	1.001	345	3412177
	0.27%	2281	0.27%	1.000	2267	0.994	292	2356604

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
snp-02-004-104	0.00%	13214	0.00%	1.000	14561	1.102	1021	66292537
	0.00%	13792	0.00%	1.000	18040	1.308	1027	66670952
	0.00%	20296	0.00%	1.000	19680	0.970	761	49407474
sorrell3	43.77%	41816	43.81%	1.000	41208	0.985	0	0
	35.59%	39431	35.59%	1.000	39514	1.002	0	0
	19.11%	8842	19.11%	1.000	8801	0.995	0	0
sp150x300d	3.97	3472	3.96	0.997	3472	1.000	483	7352
	3.08	2569	3.12	1.013	2569	1.000	379	7030
	1.25	848	1.29	1.032	848	1.000	154	3892
sp97ar	0.98%	15747	0.98%	1.000	15747	1.000	0	0
	1.02%	22961	1.02%	1.000	22961	1.000	0	0
	1.53%	24828	1.53%	1.000	24828	1.000	0	0
sp98ar	1.43%	71905	1.43%	1.000	71746	0.998	0	0
	0.48%	67033	0.48%	1.000	67060	1.000	0	0
	0.98%	70824	0.98%	1.000	71271	1.006	0	0
splice1k1	309.20%	513	309.20%	1.000	513	1.000	0	0
	376.10%	588	376.10%	1.000	594	1.010	0	0
	358.74%	837	358.74%	1.000	834	0.996	0	0
square41	109.98%	30	109.98%	1.000	30	1.000	0	0
	89.32%	38	89.32%	1.000	37	0.974	0	0
	92.32%	28	92.32%	1.000	28	1.000	0	0
square47	231.21%	4	231.21%	1.000	4	1.000	0	0
	117.00%	13	117.00%	1.000	13	1.000	0	0
	231.21%	1	231.21%	1.000	1	1.000	0	0
supportcase10	803.51%	1	803.51%	1.000	1	1.000	0	0
	989.07%	1	989.07%	1.000	1	1.000	0	0
	1054.36%	1	1054.36%	1.000	1	1.000	0	0
supportcase12	1.31%	1467	1.31%	1.000	1463	0.997	4	3668
	1.35%	2282	1.35%	1.000	2297	1.007	3	9352
	1.30%	1505	1.30%	1.000	1505	1.000	0	0
supportcase18	3.84%	420841	3.84%	1.000	419350	0.996	0	0
	5.96%	236784	5.96%	1.000	237591	1.003	0	0
	3.84%	198854	3.84%	1.000	198815	1.000	0	0
supportcase19	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
supportcase22	∞	51	∞	1.000	51	1.000	0	0
	∞	18	∞	1.000	18	1.000	0	0
	∞	66	∞	1.000	66	1.000	0	0
supportcase26	8.97%	8093481	8.94%	1.000	8135621	1.005	0	0
	5245.24	6761735	5238.22	0.999	6761735	1.000	0	0
	4513.92	5497025	4487.28	0.994	5497025	1.000	0	0
supportcase33	1603.38	12756	1598.38	0.997	12756	1.000	0	0
	1613.08	7176	1600.98	0.992	7176	1.000	0	0
	686.38	3786	682.16	0.994	3786	1.000	0	0
supportcase40	785.32	6335	786.50	1.002	6335	1.000	3435	3882029
	895.45	7377	946.94	*1.058*	7991	*1.083*	3287	3679797
	1262.35	13443	797.74	**0.632**	6970	**0.518**	3246	3640658
supportcase42	0.25%	360836	0.38%	1.000	305571	0.847	8724	105301052
	0.13%	375683	0.10%	1.000	380155	1.012	10045	120744588
	0.10%	393957	0.35%	1.000	467610	1.187	12490	150888216
supportcase6	9.13%	19067	9.13%	1.000	18980	0.995	0	0
	8.41%	17731	8.41%	1.000	17726	1.000	0	0
	9.74%	17577	9.72%	1.000	17709	1.008	0	0
supportcase7	183.33	59	179.98	0.982	59	1.000	20	144588
	193.92	45	193.62	0.998	45	1.000	50	353440

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Table A.2: Detailed computational results on MIPLIB 2017 benchmark with and without nonzero cancellation with variable bounds.

	bound-cancellation disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	#BC	BC
	212.36	32	210.25	0.990	32	1.000	58	412750
swath1	24.58	287	21.09	**0.858**	281	0.979	454	1376538
	17.70	245	17.34	0.980	245	1.000	400	1114929
	24.35	294	19.82	**0.814**	292	0.993	461	1323181
swath3	194.53	20962	226.20	*1.163*	28316	*1.351*	2976	5359114
	185.36	21524	182.91	0.987	21837	1.015	2503	5135046
	423.46	73931	427.45	1.009	74192	1.004	6596	9134234
tbfp-network	2324.14	574	2356.81	1.014	574	1.000	0	0
	1692.27	71	1683.80	0.995	71	1.000	0	0
	1094.11	99	1088.57	0.995	99	1.000	0	0
thor50dday	23.30%	102	23.30%	1.000	95	0.931	7	137376
	21.49%	11	21.49%	1.000	12	1.091	1	15902
	14.80%	33	14.80%	1.000	34	1.030	0	0
timtab1	67.33	55554	73.73	*1.095*	64175	*1.155*	3180	13023
	75.16	59915	67.90	**0.903**	51540	**0.860**	2308	9403
	74.07	56992	70.92	0.957	55054	0.966	3368	14105
tr12-30	719.89	499158	606.97	**0.843**	423661	**0.849**	1462	18234
	619.77	456738	650.32	1.049	475420	1.041	909	6551
	448.35	263384	397.52	**0.887**	213946	**0.812**	6901	86516
traininstance2	∞	66199	∞	1.000	67099	1.014	0	0
	∞	50671	∞	1.000	52063	1.027	0	0
	6286.13%	73943	6286.13%	1.000	73138	0.989	0	0
traininstance6	632.46%	456745	634.16%	1.000	456248	0.999	0	0
	626.92%	346228	626.92%	1.000	347529	1.004	0	0
	524.49%	451546	520.12%	1.000	454368	1.006	0	0
trento1	0.07%	58583	0.07%	1.000	57766	0.986	11359	107265
	0.14%	39213	0.10%	1.000	51033	1.301	9360	85619
	0.09%	46478	1.67%	1.000	35013	0.753	4102	22028
triptim1	1094.23	8	1099.43	1.005	8	1.000	0	0
	748.83	7	747.73	0.999	7	1.000	0	0
	1061.97	8	1065.09	1.003	8	1.000	0	0
uccase12	0.00%	78128	0.00%	1.000	77800	0.996	950	7994835
	0.00%	95474	0.00%	1.000	91468	0.958	1028	8631329
	0.00%	88904	0.00%	1.000	98605	1.109	689	5594630
uccase9	1.57%	482	1.98%	1.000	498	1.033	79	570590
	5.01%	941	1.48%	1.000	1166	1.239	70	509055
	3.47%	669	2.82%	1.000	550	0.822	74	553523
uct-subprob	1109.37	44339	1102.62	0.994	44339	1.000	0	0
	1628.10	59559	1631.60	1.002	59559	1.000	0	0
	2489.68	95674	2506.36	1.007	95674	1.000	0	0
unitcal_7	271.08	91	272.59	1.006	89	0.978	65	87377
	297.46	176	298.12	1.002	180	1.023	163	200638
	385.89	436	387.18	1.003	436	1.000	117	133914
var-smallemery-m6j6	0.93%	565917	0.93%	1.000	568323	1.004	3995	3995
	0.87%	657875	0.87%	1.000	656232	0.998	2386	2386
	6763.76	683202	6729.45	0.995	683202	1.000	8795	8795
wachplan	2345.94	219938	2340.84	0.998	219938	1.000	0	0
	3425.94	302179	3419.67	0.998	302179	1.000	0	0
	2346.42	198054	2343.95	0.999	198054	1.000	0	0

Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
30n20b8	149.46	171	149.68	1.001	171	1.000	40	111	0
	902.33	2334	623.60	**0.691**	1999	**0.856**	678	1459	14
	1993.61	6739	693.56	**0.348**	3499	**0.519**	1293	2668	6
50v-10	1.46%	842135	1.69%	1.000	829421	0.985	0	0	0
	1.31%	954981	1.15%	1.000	867997	0.909	0	0	0
	1.27%	921415	1.37%	1.000	833134	0.904	0	0	0
CMS750_4	185.43	2028	185.73	1.002	2028	1.000	0	0	0
	369.97	3254	370.72	1.002	3254	1.000	0	0	0
	477.67	13518	473.12	0.990	13518	1.000	0	0	0
academictimetablesmall	∞	2306	∞	1.000	2315	1.004	0	0	0
	∞	3503	∞	1.000	3505	1.001	0	0	0
	∞	2681	∞	1.000	2681	1.000	0	0	0
air05	40.09	648	40.07	1.000	648	1.000	0	0	0
	36.49	716	36.54	1.001	716	1.000	0	0	0
	30.44	282	30.22	0.993	282	1.000	0	0	0
app1-1	3.52	2	3.53	1.003	2	1.000	0	0	0
	4.86	3	4.94	1.016	3	1.000	0	0	0
	4.20	6	4.17	0.993	6	1.000	1	2	0
app1-2	643.76	33	642.80	0.999	33	1.000	0	0	0
	792.56	20	789.47	0.996	20	1.000	0	0	0
	620.83	20	618.36	0.996	20	1.000	0	0	0
assign1-5-8	4.74%	5732154	4.74%	1.000	5736357	1.001	960	992	4
	4.55%	6747183	4.54%	1.000	6813236	1.010	1059	1178	4
	4.79%	6372276	4.80%	1.000	6333262	0.994	1701	1838	26
atlanta-ip	7.06%	18035	3.60%	1.000	18533	1.028	459	6857	2
	3.33%	16022	3.81%	1.000	21153	1.320	842	11057	1
	6.53%	25264	4.27%	1.000	30903	1.223	685	16019	0
b1c1s1	16.96%	49593	17.13%	1.000	35962	0.725	5134	432099	12
	15.64%	18924	18.36%	1.000	21112	1.116	3174	277493	9
	17.51%	18530	17.69%	1.000	18673	1.008	3478	260211	6
bab2	1.29%	3468	1.29%	1.000	3473	1.001	0	0	0
	1.10%	3325	2.44%	1.000	3262	0.981	0	0	0
	∞	1934	∞	1.000	1981	1.024	0	0	0
bab6	0.58%	4900	0.58%	1.000	4790	0.978	0	0	0
	0.83%	3265	1.14%	1.000	3258	0.998	0	0	0
	1.94%	4770	1.94%	1.000	4779	1.002	0	0	0
beasleyC3	31.53	83	31.56	1.001	83	1.000	1	27	0
	17.31	2	17.35	1.002	2	1.000	0	0	0
	46.61	422	47.20	1.013	453	*1.073*	177	1447	0
binkar10_1	33.57	2517	31.34	**0.934**	2560	1.017	1240	7279	0
	35.96	2777	29.22	**0.813**	2246	**0.809**	1197	8144	0
	34.91	3245	28.71	**0.822**	2509	**0.773**	1361	8621	1
blp-ar98	0.27%	237012	0.27%	1.000	238231	1.005	0	0	0
	0.33%	207612	0.33%	1.000	207500	0.999	0	0	0
	0.32%	227469	0.32%	1.000	229423	1.009	0	0	0
blp-ic98	1.38%	306270	1.38%	1.000	304769	0.995	0	0	0
	2.41%	253836	2.41%	1.000	254061	1.001	0	0	0
	2.11%	277183	2.11%	1.000	278188	1.004	0	0	0
bnatt400	971.53	6821	970.91	0.999	6821	1.000	0	0	0
	1098.53	6346	1105.02	1.006	6346	1.000	0	0	0
	744.01	5500	745.15	1.002	5500	1.000	0	0	0
bnatt500	4375.67	29526	4368.17	0.998	29526	1.000	0	0	0
	6333.53	38962	6333.06	1.000	38962	1.000	0	0	0
	4953.66	29029	4996.90	1.009	29029	1.000	0	0	0
bppc4-08	1.92%	796242	1.92%	1.000	797503	1.002	0	0	0

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
	1.92%	931523	1.92%	1.000	938927	1.008	0	0	0
	1.92%	795486	1.92%	1.000	793397	0.997	0	0	0
brazil3	3372.83	2570	3360.46	0.996	2570	1.000	0	0	0
	4262.59	2347	4252.19	0.998	2347	1.000	0	0	0
	3798.56	3302	3785.08	0.996	3302	1.000	0	0	0
buildingenergy	0.13%	96	0.13%	1.000	96	1.000	95	1157	0
	0.15%	85	0.15%	1.000	85	1.000	234	6070	0
	0.13%	11	0.13%	1.000	12	1.091	0	0	0
cbs-cta	40.16	1	40.27	1.003	1	1.000	0	0	0
	312.39	31	314.10	1.005	31	1.000	0	0	0
	35.54	1	35.77	1.006	1	1.000	0	0	0
chromaticindex1024-7	33.33%	965	33.33%	1.000	964	0.999	0	0	0
	33.33%	1171	33.33%	1.000	1171	1.000	0	0	0
	6422.81	757	6429.72	1.001	757	1.000	0	0	0
chromaticindex512-7	1186.43	361	1172.37	0.988	361	1.000	0	0	0
	3697.86	3133	3689.97	0.998	3133	1.000	0	0	0
	33.33%	40637	33.33%	1.000	40579	0.999	0	0	0
cmflsp50-24-8-8	3.97%	39309	3.98%	1.000	36090	0.918	4145	4645516	549
	1.41%	63823	1.99%	1.000	85475	1.339	8145	5052250	29
	2.87%	39253	4.86%	1.000	37790	0.963	4752	4640838	169
co-100	1.75%	53888	1.74%	1.000	54008	1.002	0	0	0
	91.90%	6911	91.77%	1.000	7012	1.015	0	0	0
	3.28%	10392	3.18%	1.000	10565	1.017	0	0	0
cod105	47.41%	7351	47.57%	1.000	7261	0.988	0	0	0
	48.00%	6831	48.00%	1.000	6829	1.000	0	0	0
	48.07%	6601	48.07%	1.000	6601	1.000	0	0	0
comp07-2idx	966.67%	4002	966.67%	1.000	3996	0.999	0	0	0
	2800.00%	756	2800.00%	1.000	743	0.983	0	0	0
	1716.67%	1421	1716.67%	1.000	1449	1.020	0	0	0
comp21-2idx	247.43%	10922	247.43%	1.000	10931	1.001	850	850	0
	195.39%	9851	195.50%	1.000	9835	0.998	1497	1497	0
	248.72%	11719	248.72%	1.000	11711	0.999	210	210	0
cost266-UUE	5308.10	429467	4923.15	**0.927**	375684	**0.875**	3071	3825	0
	4336.47	321297	3728.83	**0.860**	294630	**0.917**	3277	4109	0
	4817.89	393239	4067.72	**0.844**	306702	**0.780**	2977	3606	0
cryptanalysiskb128n5obj14	∞	110	∞	1.000	110	1.000	27	69	0
	∞	60	∞	1.000	59	0.983	6	12	0
	∞	90	∞	1.000	90	1.000	10	12	0
cryptanalysiskb128n5obj16	∞	102	∞	1.000	104	1.020	16	21	1
	2793.60	37	2790.65	0.999	37	1.000	6	20	0
	∞	97	∞	1.000	97	1.000	24	30	0
csched007	2365.33	188163	2327.77	0.984	187288	0.995	230	336	1
	2836.56	253975	2613.95	**0.922**	220934	**0.870**	28458	107892	4
	2928.44	236575	3393.08	*1.159*	247755	1.047	30510	99040	43
csched008	5642.08	538941	2.81%	1.276	455870	0.846	50411	86777	5206
	4488.44	354389	2.33%	1.604	694455	1.960	41848	57525	4297
	3959.91	446069	5772.95	*1.458*	546382	*1.225*	57820	80863	6112
cvs16r128-89	23.28%	67974	23.28%	1.000	67980	1.000	0	0	0
	22.61%	34962	22.61%	1.000	34973	1.000	0	0	0
	23.00%	47519	23.01%	1.000	47219	0.994	0	0	0
dano3_3	143.27	10	143.70	1.003	10	1.000	7	14	0
	139.35	14	142.65	1.024	14	1.000	8	47	0
	124.76	17	124.56	0.998	17	1.000	7	59	0
dano3_5	641.80	276	635.04	0.989	276	1.000	215	12596	0
	285.77	159	285.81	1.000	159	1.000	164	3429	0
	286.86	140	285.94	0.997	140	1.000	66	2080	0

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
decomp2	2.43	1	2.39	0.984	1	1.000	0	0	0
	2.44	1	2.42	0.992	1	1.000	0	0	0
	2.44	1	2.50	1.025	1	1.000	0	0	0
drayage-100-23	16.41	32	16.43	1.001	32	1.000	0	0	0
	19.60	48	19.52	0.996	48	1.000	0	0	0
	13.49	16	13.50	1.001	16	1.000	0	0	0
drayage-25-23	0.07%	722284	0.07%	1.000	720814	0.998	0	0	0
	0.07%	794527	0.07%	1.000	790871	0.995	0	0	0
	6923.71	552534	6941.84	1.003	552534	1.000	0	0	0
dws008-01	52.26%	147234	44.84%	1.000	144766	0.983	75033	8450388	2594
	50.24%	153128	44.28%	1.000	157395	1.028	74230	8346962	1341
	45.74%	159713	52.63%	1.000	153108	0.959	71740	7187186	969
eil33-2	79.52	343	81.20	1.021	343	1.000	0	0	0
	102.50	395	101.92	0.994	395	1.000	0	0	0
	105.71	541	105.72	1.000	541	1.000	0	0	0
eilA101-2	20.05%	11030	20.05%	1.000	11110	1.007	0	0	0
	13.20%	12683	13.20%	1.000	12688	1.000	0	0	0
	13.37%	13542	13.37%	1.000	13480	0.995	0	0	0
enlight_hard	0.50	1	0.50	1.000	1	1.000	0	0	0
	0.50	1	0.50	1.000	1	1.000	0	0	0
	0.50	1	0.50	1.000	1	1.000	0	0	0
ex10	492.89	1	493.80	1.002	1	1.000	0	0	0
	501.87	1	497.94	0.992	1	1.000	0	0	0
	578.19	1	581.12	1.005	1	1.000	0	0	0
ex9	28.90	1	27.98	0.968	1	1.000	0	0	0
	27.40	1	27.30	0.996	1	1.000	0	0	0
	27.37	1	27.02	0.987	1	1.000	0	0	0
exp-1-500-5-5	2.26	1	2.28	1.009	1	1.000	1	10	0
	2.25	1	2.22	0.987	1	1.000	1	10	0
	2.22	1	2.21	0.995	1	1.000	1	10	0
fast0507	321.56	1284	322.23	1.002	1284	1.000	0	0	0
	278.55	1223	280.17	1.006	1223	1.000	0	0	0
	364.27	1711	365.44	1.003	1711	1.000	0	0	0
fastxgemm-n2r6s0t2	3502.66	824448	4702.82	*1.343*	1118937	*1.357*	60810	1584297	4898
	4248.99	1034836	4017.11	**0.945**	1012967	0.979	46119	1227625	4252
	3917.93	929719	3129.08	**0.799**	769500	**0.828**	31382	742061	3380
fhnw-binpack4-48	∞	4074733	∞	1.000	4040499	0.992	0	0	0
	∞	3516591	∞	1.000	3525851	1.003	0	0	0
	∞	3420906	∞	1.000	3413924	0.998	0	0	0
fhnw-binpack4-4	∞	14366166	∞	1.000	14733968	1.026	51	62	0
	∞	11775368	∞	1.000	13981261	1.187	134	154	1
	∞	13192866	∞	1.000	11607995	0.880	16	18	0
fiball	303.30	1648	465.55	*1.535*	4111	*2.495*	0	0	0
	449.28	3521	447.14	0.995	3521	1.000	0	0	0
	501.25	5672	499.03	0.996	5672	1.000	0	0	0
gen-ip002	1311.44	5832063	1315.68	1.003	5856334	1.004	0	0	0
	1222.63	5492464	1295.56	*1.060*	5478569	0.997	0	0	0
	1418.15	5917739	1271.92	**0.897**	5583912	**0.944**	0	0	0
gen-ip054	2293.06	11460069	3047.64	*1.329*	15245360	*1.330*	0	0	0
	2676.80	13353033	2530.93	**0.946**	12476019	**0.934**	0	0	0
	3264.40	16306455	3381.24	1.036	16438070	1.008	0	0	0
germanrr	2.11%	6179	1.46%	1.000	3418	0.553	1296	930657	6012
	1.61%	4773	2.11%	1.000	2851	0.597	1008	674103	6698
	2.12%	5323	1.94%	1.000	3559	0.669	1188	692698	5680
gfd-schedulen180f7d50m30k18	∞	4	∞	1.000	4	1.000	0	0	0
	∞	9	∞	1.000	8	0.889	0	0	0

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
	∞	10	∞	1.000	10	1.000	0	0	0
glass-sc	2649.20	241329	2655.26	1.002	241329	1.000	0	0	0
	3219.69	289206	3214.67	0.998	289206	1.000	0	0	0
	2820.67	251112	2819.06	0.999	251112	1.000	0	0	0
glass4	1436.38	1198005	4008.75	*2.791*	2705421	*2.258*	20465	44945	88
	2209.95	1777925	2392.84	*1.083*	1888717	*1.062*	13000	28057	48
	3657.58	3399800	2212.84	**0.605**	1599046	**0.470**	8277	17765	39
gmu-35-40	0.02%	2015603	0.05%	1.000	2051936	1.018	0	0	0
	0.03%	2078303	0.03%	1.000	2099939	1.010	0	0	0
	0.03%	1384935	0.03%	1.000	1381092	0.997	0	0	0
gmu-35-50	0.02%	1215213	0.02%	1.000	1317781	1.084	0	0	0
	0.03%	1233124	0.03%	1.000	1247342	1.012	0	0	0
	0.04%	1017587	0.04%	1.000	1016723	0.999	0	0	0
graph20-20-1rand	163.73%	6141	163.73%	1.000	6171	1.005	0	0	0
	165.38%	8297	165.38%	1.000	8277	0.998	0	0	0
	172.66%	7506	172.66%	1.000	7513	1.001	0	0	0
graphdraw-domain	1027.09	1921032	1010.47	0.984	1823083	**0.949**	27570	108505	8
	1275.78	2267753	1122.85	**0.880**	1941578	**0.856**	34372	128150	27
	1309.75	2462138	1664.67	*1.271*	2907888	*1.181*	32887	126476	14
h80x6320d	69.51	4	69.54	1.000	4	1.000	5	272	0
	85.96	10	86.17	1.002	10	1.000	36	321	0
	83.19	5	86.62	1.041	5	1.000	12	292	0
highschool1-aigio	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
hypothyroid-k1	20.03	1	20.04	1.000	1	1.000	0	0	0
	20.14	1	19.99	0.993	1	1.000	0	0	0
	20.10	1	20.16	1.003	1	1.000	0	0	0
ic97_potential	0.93%	7108440	0.84%	1.000	7214792	1.015	84920	224548	13768
	0.52%	5988038	0.75%	1.000	6107856	1.020	97136	233798	16056
	0.78%	7276195	0.86%	1.000	7579116	1.042	77811	213437	12467
icir97_tension	0.09%	2933900	0.07%	1.000	3185773	1.086	67327	344855	928
	6818.43	3051060	0.05%	1.056	2776552	0.910	104698	382048	1002
	0.09%	2846197	0.08%	1.000	2729235	0.959	61307	244198	479
irish-electricity	∞	93	∞	1.000	93	1.000	0	0	0
	26.52%	1693	18.43%	1.000	1317	0.778	89	39582	2
	∞	1333	∞	1.000	1333	1.000	337	5098	0
irp	12.40	6	12.51	1.009	6	1.000	0	0	0
	12.01	4	12.05	1.003	4	1.000	0	0	0
	12.56	5	12.58	1.002	5	1.000	0	0	0
istanbul-no-cutoff	149.11	347	154.02	1.033	347	1.000	66	185	0
	167.55	290	166.34	0.993	245	**0.845**	38	73	0
	297.83	502	285.14	0.957	475	**0.946**	73	113	0
k1mushroom	1856.86	7	1897.56	1.022	7	1.000	0	0	0
	1582.93	11	1583.93	1.001	11	1.000	0	0	0
	1321.39	3	1321.29	1.000	3	1.000	0	0	0
lectsched-5-obj	106.67%	138890	166.67%	1.000	148725	1.071	837	921	7
	100.00%	210835	120.00%	1.000	130812	0.620	468	568	8
	126.67%	65555	126.67%	1.000	64923	0.990	763	901	13
leo1	6.11%	80656	6.11%	1.000	80819	1.002	0	0	0
	7.14%	34875	7.14%	1.000	34905	1.001	0	0	0
	7.53%	45860	7.53%	1.000	45969	1.002	0	0	0
leo2	∞	101644	∞	1.000	101616	1.000	0	0	0
	∞	111132	∞	1.000	110967	0.999	0	0	0
	∞	146904	∞	1.000	146706	0.999	0	0	0
lotsize	0.59%	17696	0.67%	1.000	16786	0.949	10346	265616	25

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
	0.83%	19280	0.88%	1.000	20493	1.063	14718	624095	0
	0.64%	18285	0.70%	1.000	17911	0.980	11090	555863	1
mad	∞	10114842	∞	1.000	8295624	0.820	0	0	0
	∞	19840612	∞	1.000	14934806	0.753	0	0	0
	∞	15915645	∞	1.000	15381075	0.966	0	0	0
map10	1016.84	1752	1006.71	0.990	1637	**0.934**	474	212302	0
	630.06	724	633.84	1.006	724	1.000	446	181921	0
	804.26	979	792.96	0.986	965	0.986	491	196147	0
map16715-04	2163.19	1963	2158.43	0.998	1933	0.985	1083	841521	0
	2367.79	2208	2335.51	0.986	2173	0.984	969	691969	0
	2108.62	2038	2160.04	1.024	1990	0.976	1158	882361	0
markshare2	∞	5803228	∞	1.000	5827069	1.004	0	0	0
	∞	5608533	∞	1.000	5581862	0.995	0	0	0
	∞	5025745	∞	1.000	5052479	1.005	0	0	0
markshare_4_0	73.22	612396	72.47	0.990	612396	1.000	0	0	0
	70.45	589762	70.48	1.000	589762	1.000	0	0	0
	86.21	719508	85.88	0.996	719508	1.000	0	0	0
mas74	1681.25	4932223	1680.79	1.000	4932223	1.000	0	0	0
	2315.16	7992953	2282.09	0.986	7992914	1.000	0	0	0
	1600.10	4642890	1563.59	0.977	4674399	1.007	0	0	0
mas76	137.17	417210	136.88	0.998	406104	0.973	0	0	0
	174.18	542396	168.46	0.967	525538	0.969	0	0	0
	147.94	449431	152.65	1.032	450422	1.002	0	0	0
mc11	132.52	5754	149.40	*1.127*	6484	*1.127*	2031	8841	0
	91.51	2220	80.39	**0.878**	1411	**0.636**	547	2836	0
	95.10	2350	106.11	*1.116*	3386	*1.441*	1339	8682	0
mcsched	318.23	11378	318.21	1.000	11378	1.000	0	0	0
	235.42	9846	235.33	1.000	9846	1.000	0	0	0
	305.24	12017	306.32	1.004	12017	1.000	0	0	0
mik-250-20-75-4	52.59	23893	52.78	1.004	23893	1.000	0	0	0
	43.86	15175	43.96	1.002	15175	1.000	0	0	0
	52.22	20733	52.36	1.003	20733	1.000	0	0	0
milo-v12-6-r2-40-1	10.25%	262756	9.47%	1.000	189681	0.722	29443	793993	8057
	12.14%	300898	8.96%	1.000	323326	1.075	48855	996254	9224
	12.55%	157419	11.33%	1.000	417232	2.650	50731	1460603	21597
momentum1	15.92%	109291	24.76%	1.000	94037	0.860	16334	3142408	146
	6.21%	196564	7.36%	1.000	91471	0.465	19615	3121036	101
	7.40%	196735	6.53%	1.000	188055	0.956	24263	3816211	95
mushroom-best	655.70	32432	579.50	**0.884**	27393	**0.845**	2354	63226	2347
	162.32%	93046	134.09%	1.000	94624	1.017	2438	8272	1397
	121.99%	91607	121.97%	1.000	98893	1.080	2289	9665	3624
mzzv11	210.47	484	210.71	1.001	484	1.000	151	2944	1
	295.69	1237	263.08	**0.890**	987	**0.798**	93	1908	8
	195.49	616	195.89	1.002	616	1.000	131	2863	0
mzzv42z	170.41	366	175.26	1.028	415	*1.134*	41	491	2
	245.85	712	246.00	1.001	712	1.000	119	1129	1
	307.42	719	306.34	0.996	719	1.000	84	790	14
n2seq36q	928.18	5438	936.81	1.009	5438	1.000	0	0	0
	1068.12	4712	1061.28	0.994	4712	1.000	0	0	0
	1165.81	4632	1170.79	1.004	4632	1.000	0	0	0
n3div36	2.59%	214521	2.59%	1.000	213866	0.997	0	0	0
	2.86%	206708	2.86%	1.000	207136	1.002	0	0	0
	2.69%	203288	2.69%	1.000	202891	0.998	0	0	0
n5-3	26.44	926	26.40	0.998	926	1.000	0	0	0
	27.87	971	27.79	0.997	971	1.000	0	0	0
	27.03	1087	27.09	1.002	1087	1.000	0	0	0

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
neos-1122047	9.85	1	9.92	1.007	1	1.000	0	0	0
	10.12	1	9.76	0.964	1	1.000	0	0	0
	10.02	1	9.70	0.968	1	1.000	0	0	0
neos-1171448	57.62	101	58.11	1.009	101	1.000	1	2	0
	5.14	1	5.16	1.004	1	1.000	1	2	0
	51.32	86	51.55	1.004	86	1.000	1	2	0
neos-1171737	1.04%	3914	1.04%	1.000	3912	0.999	201	39010	9
	1.56%	3995	1.56%	1.000	4009	1.004	146	22485	2
	1.04%	23961	1.30%	1.000	11719	0.489	870	171876	48
neos-1354092	∞	613	∞	1.000	613	1.000	16	44	0
	∞	820	∞	1.000	820	1.000	8	40	0
	∞	639	∞	1.000	639	1.000	13	51	0
neos-1445765	43.55	133	43.72	1.004	133	1.000	0	0	0
	44.21	141	44.19	1.000	141	1.000	0	0	0
	44.33	125	44.74	1.009	125	1.000	0	0	0
neos-1456979	7.49%	39962	7.49%	1.000	39961	1.000	317	342	0
	6.84%	38683	6.84%	1.000	38750	1.002	386	411	0
	7.31%	31468	7.29%	1.000	31540	1.002	260	295	2
neos-1582420	22.35	18	21.85	0.978	18	1.000	99	748	0
	10.95	9	10.92	0.997	9	1.000	23	183	0
	56.60	1485	55.49	0.980	1381	**0.930**	343	6636	3
neos-2075418-temuka	6994.03	1	7024.05	1.004	1	1.000	0	0	0
	4557.40	1	4517.94	0.991	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
neos-2657525-crna	∞	1033738	∞	1.000	3064132	2.964	305338	1287499	4384
	∞	6445549	∞	1.000	3681104	0.571	260563	1054254	4131
	∞	2050011	∞	1.000	2122332	1.035	167202	651015	2934
neos-2746589-doon	0.46%	55574	0.46%	1.000	55681	1.002	55	59	0
	0.73%	30244	0.73%	1.000	30280	1.001	17	17	0
	0.11%	183064	0.11%	1.000	182349	0.996	16	16	0
neos-2978193-inde	0.50%	556781	0.50%	1.000	549249	0.986	17677	1380705	6909
	0.13%	592342	0.13%	1.000	573707	0.969	15133	278686	11049
	0.50%	554918	0.50%	1.000	548119	0.988	14906	869905	5391
neos-2987310-joes	17.78	1	17.49	0.984	1	1.000	0	0	0
	15.38	1	15.31	0.995	1	1.000	0	0	0
	13.98	1	13.67	0.978	1	1.000	0	0	0
neos-3004026-krka	53.47	2711	53.06	0.992	2711	1.000	0	0	0
	62.71	3485	62.47	0.996	3485	1.000	0	0	0
	46.89	1764	46.28	0.987	1764	1.000	0	0	0
neos-3024952-loue	0.16%	539688	4646.86	**0.645**	383076	**0.710**	0	0	0
	0.04%	572811	0.07%	1.000	688312	1.202	0	0	0
	0.06%	712436	0.04%	1.000	1114650	1.565	0	0	0
neos-3046615-murg	168.57%	6790987	169.81%	1.000	6971706	1.027	44944	176979	361
	165.23%	6304071	166.11%	1.000	6364063	1.010	52191	188828	378
	165.34%	6624957	163.66%	1.000	7613539	1.149	53660	197797	217
neos-3083819-nubu	12.85	2020	12.72	0.990	2020	1.000	0	0	0
	12.41	1578	12.37	0.997	1578	1.000	0	0	0
	13.15	1783	20.79	*1.581*	3812	*2.138*	0	0	0
neos-3216931-puriri	121.93%	5930	116.41%	1.000	5546	0.935	1653	18527	171
	136.59%	7016	5.50%	1.000	9705	1.383	3122	31056	292
	44.24%	7052	147.13%	1.000	4790	0.679	1084	12570	125
neos-3381206-awhea	1.17	1	1.18	1.009	1	1.000	0	0	0
	1.18	1	1.21	1.025	1	1.000	0	0	0
	1.58	1	1.20	**0.759**	1	1.000	0	0	0
neos-3402294-bobin	4393.77	40294	4386.37	0.998	40294	1.000	0	0	0
	626.24	3428	618.95	0.988	3428	1.000	0	0	0

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
	1615.76	9242	1620.92	1.003	9242	1.000	0	0	0
neos-3402454-bohle	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
neos-3555904-turama	18.01%	145	18.01%	1.000	145	1.000	0	0	0
	∞	18	∞	1.000	18	1.000	0	0	0
	18.01%	16848	18.01%	1.000	16797	0.997	0	0	0
neos-3627168-kasai	0.15%	4666430	0.15%	1.000	4555684	0.976	247098	1484594	60869
	0.08%	3864489	0.09%	1.000	4132791	1.069	128677	534359	5538
	0.32%	4890974	0.27%	1.000	5147129	1.052	200184	1553577	21135
neos-3656078-kumeu	∞	32	∞	1.000	32	1.000	2	10	0
	∞	82	∞	1.000	82	1.000	7	6	4
	∞	120	∞	1.000	122	1.017	20	28	9
neos-3754480-nidda	∞	19392247	∞	1.000	20000763	1.031	404243	2137015	0
	∞	17983261	∞	1.000	18439214	1.025	334081	1932375	0
	∞	18621407	∞	1.000	19108471	1.026	318601	1714950	0
neos-3988577-wolgan	∞	309	∞	1.000	312	1.010	0	0	0
	∞	179	∞	1.000	179	1.000	0	0	0
	∞	439	∞	1.000	439	1.000	0	0	0
neos-4300652-rahue	431.97%	1366	431.97%	1.000	1365	0.999	857	556334	33
	809.48%	1234	809.48%	1.000	1213	0.983	671	435322	135
	316.83%	2125	316.83%	1.000	2127	1.001	862	558266	51
neos-4338804-snowy	2.07%	4480880	1.66%	1.000	4875741	1.088	4688	7594	60
	0.82%	6599181	0.82%	1.000	6738902	1.021	5834	9204	62
	1.80%	4918723	1.66%	1.000	5067404	1.030	3873	7160	29
neos-4387871-tavua	15.21%	101425	11.39%	1.000	118375	1.167	16112	2131445	18596
	11.14%	129374	14.13%	1.000	116171	0.898	19318	2188084	25944
	16.55%	90590	18.66%	1.000	96695	1.067	17305	2381097	26390
neos-4413714-turia	295.68	2	299.23	1.012	2	1.000	0	0	0
	403.01	2	404.80	1.004	2	1.000	0	0	0
	285.26	2	277.10	0.971	2	1.000	0	0	0
neos-4532248-waihi	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
neos-4647030-tutaki	0.01%	24564	0.01%	1.000	24413	0.994	34	1457	0
	0.01%	23168	0.01%	1.000	22893	0.988	34	3708	0
	0.01%	26780	0.01%	1.000	27292	1.019	39	276	0
neos-4722843-widden	4370.53	21244	2651.33	**0.607**	11357	**0.535**	3551	4044	15
	884.93	3347	1033.65	*1.168*	3376	1.009	506	925	1
	2413.56	11399	1714.52	**0.710**	7919	**0.695**	1494	5039	43
neos-4738912-atrato	950.47	90901	813.40	**0.856**	61981	**0.682**	168	704	0
	3625.90	323637	3808.90	*1.050*	324992	1.004	60	293	0
	881.55	90544	914.39	1.037	95736	*1.057*	2085	8935	0
neos-4763324-toguru	46.04%	8436	46.04%	1.000	8436	1.000	176	176	0
	45.08%	14925	45.08%	1.000	14962	1.002	274	274	0
	48.94%	7145	48.94%	1.000	7145	1.000	147	147	0
neos-4954672-berkel	9.85%	1090964	8.48%	1.000	1019990	0.935	108821	3526157	0
	8.67%	801213	8.71%	1.000	819107	1.022	102348	3809289	0
	8.26%	863316	8.00%	1.000	891993	1.033	115288	3611058	2
neos-5049753-cuanza	∞	52	∞	1.000	52	1.000	0	0	0
	15.39%	14	15.39%	1.000	14	1.000	0	0	0
	15.20%	12	15.20%	1.000	12	1.000	0	0	0
neos-5052403-cygnet	1.60%	113	1.60%	1.000	113	1.000	0	0	0
	1.38%	1	1.38%	1.000	1	1.000	0	0	0
	1.19%	63	1.19%	1.000	63	1.000	0	0	0
neos-5093327-huahum	10.59%	49160	10.32%	1.000	49854	1.014	5081	2892297	0

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
	10.40%	51911	10.43%	1.000	52521	1.012	5112	2880628	0
	8.03%	61483	12.17%	1.000	48532	0.789	5859	3208411	2
neos-5104907-jarama	∞	8	∞	1.000	8	1.000	0	0	0
	∞	9	∞	1.000	9	1.000	1	4	0
	∞	4	∞	1.000	4	1.000	1	5	0
neos-5107597-kakapo	2198.25	613736	2144.47	0.976	560533	**0.913**	11	10	1
	2305.69	750515	1725.41	**0.748**	472393	**0.629**	6	8	0
	6433.70	2382549	5927.88	**0.921**	1725439	**0.724**	53	29	24
neos-5114902-kasavu	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
neos-5188808-nattai	1274.06	12152	1251.29	0.982	12145	0.999	1101	69281	1096
	1276.88	13260	1292.07	1.012	13554	1.022	1630	96022	1784
	1338.51	12446	1380.62	1.031	12548	1.008	1384	97379	1411
neos-5195221-niemur	2934.65	62937	2813.87	0.959	47466	**0.754**	87	89	4
	3296.69	29661	2911.85	**0.883**	25010	**0.843**	25	26	0
	2900.15	34651	2890.78	0.997	33779	0.975	32	33	2
neos-631710	14.21%	2	14.21%	1.000	2	1.000	0	0	0
	8.90%	4	8.90%	1.000	4	1.000	0	0	0
	14.21%	3	14.21%	1.000	3	1.000	0	0	0
neos-662469	0.00%	62896	0.01%	1.000	59651	0.948	0	0	0
	0.04%	57183	0.00%	1.000	50627	0.885	0	0	0
	0.05%	61397	0.01%	1.000	56995	0.928	0	0	0
neos-787933	1.36	1	1.37	1.007	1	1.000	0	0	0
	1.37	1	1.39	1.015	1	1.000	0	0	0
	1.39	1	1.41	1.014	1	1.000	0	0	0
neos-827175	6.17	1	6.10	0.989	1	1.000	0	0	0
	8.18	1	8.21	1.004	1	1.000	0	0	0
	10.21	1	10.23	1.002	1	1.000	0	0	0
neos-848589	32.15%	257	32.15%	1.000	256	0.996	5	264	0
	42.57%	149	42.95%	1.000	148	0.993	1	181	0
	46.27%	106	46.27%	1.000	106	1.000	1	2	0
neos-860300	17.26	2	17.27	1.001	2	1.000	0	0	0
	13.27	2	13.35	1.006	2	1.000	0	0	0
	22.98	3	23.18	1.009	3	1.000	0	0	0
neos-873061	9.28%	159	9.28%	1.000	155	0.975	16	93	6
	7.72%	148	7.72%	1.000	148	1.000	6	77	4
	8.12%	168	8.12%	1.000	168	1.000	7	8477	2
neos-911970	0.31%	3332161	1.05%	1.000	1400854	0.420	62333	694283	581
	2.34%	1566613	2.49%	1.000	1814127	1.158	121933	985857	391
	0.06%	7963827	0.06%	1.000	11460910	1.439	203731	1482860	52
neos-933966	1376.54	138	1374.28	0.998	138	1.000	0	0	0
	847.64	38	848.27	1.001	38	1.000	0	0	0
	2191.68	283	2180.73	0.995	283	1.000	0	0	0
neos-950242	100.00%	9417	100.00%	1.000	9288	0.986	0	0	0
	100.00%	8406	100.00%	1.000	8446	1.005	0	0	0
	100.00%	15615	100.00%	1.000	15629	1.001	0	0	0
neos-957323	86.64	2	86.06	0.993	2	1.000	0	0	0
	110.48	5	110.59	1.001	5	1.000	0	0	0
	79.79	2	80.10	1.004	2	1.000	0	0	0
neos-960392	882.16	15	881.09	0.999	15	1.000	0	0	0
	1459.84	102	1439.63	0.986	102	1.000	0	0	0
	1365.45	403	1363.87	0.999	403	1.000	0	0	0
neos17	26.07	22460	25.95	0.995	22460	1.000	0	0	0
	9.23	5644	9.39	1.017	5644	1.000	0	0	0
	9.76	6376	9.84	1.008	6376	1.000	0	0	0

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
neos5	1013.70	3292114	1007.54	0.994	3292114	1.000	0	0	0
	1235.27	4202380	1234.24	0.999	4202380	1.000	0	0	0
	1192.31	4100005	1183.51	0.993	4100005	1.000	0	0	0
neos859080	0.51	792	0.50	0.980	792	1.000	0	0	0
	0.58	655	0.54	**0.931**	655	1.000	2	2	0
	0.54	565	0.55	1.019	565	1.000	0	0	0
neos8	1.92	1	1.95	1.016	1	1.000	3	5	0
	1.85	1	1.89	1.022	1	1.000	3	5	0
	1.83	1	1.83	1.000	1	1.000	2	4	0
net12	2011.11	1524	1842.42	**0.916**	1211	**0.795**	243	1269	3
	1787.13	1927	1631.28	**0.913**	1816	**0.942**	416	1785	0
	2262.14	2710	1561.43	**0.690**	1695	**0.625**	326	1572	2
netdiversion	845.87	43	848.00	1.003	43	1.000	0	0	0
	2379.98	88	2364.82	0.994	88	1.000	0	0	0
	1084.62	27	1087.12	1.002	27	1.000	0	0	0
nexp-150-20-8-5	3548.55	5786	3539.59	0.997	5786	1.000	1482	1601	0
	2864.29	3863	3635.13	*1.269*	7166	*1.855*	770	944	0
	0.83%	13081	0.83%	1.000	13054	0.998	1410	1989	0
ns1116954	∞	32	∞	1.000	32	1.000	0	0	0
	∞	57	∞	1.000	57	1.000	0	0	0
	∞	75	∞	1.000	75	1.000	0	0	0
ns1208400	418.52	2004	419.49	1.002	2004	1.000	0	0	0
	682.86	2339	683.06	1.000	2339	1.000	0	0	0
	1073.99	2315	1074.09	1.000	2315	1.000	0	0	0
ns1644855	7.37%	36	7.37%	1.000	36	1.000	7	178	534
	7.37%	79	7.37%	1.000	79	1.000	3	125	162
	976.72	1	974.47	0.998	1	1.000	3	125	162
ns1760995	58.41%	1	58.41%	1.000	1	1.000	0	0	0
	71.46%	1	71.46%	1.000	1	1.000	0	0	0
	49.34%	1	48.93%	1.000	1	1.000	0	0	0
ns1830653	288.54	14558	287.45	0.996	14558	1.000	0	0	0
	133.25	7527	134.33	1.008	7527	1.000	0	0	0
	147.20	7267	148.24	1.007	7267	1.000	0	0	0
ns1952667	∞	53397	∞	1.000	52208	0.978	0	0	0
	1391.80	9508	1392.38	1.000	9508	1.000	0	0	0
	970.44	4900	968.90	0.998	4900	1.000	0	0	0
nu25-pr12	5.38	53	5.36	0.996	53	1.000	27	74	0
	6.04	66	6.11	1.012	66	1.000	18	95	0
	6.11	16	6.05	0.990	16	1.000	13	30	1
nursesched-medium-hint03	1657.78%	1118	1657.78%	1.000	1100	0.984	0	0	0
	1847.99%	2091	3021.25%	1.000	2050	0.980	0	0	0
	1077.84%	1150	1077.84%	1.000	1121	0.975	0	0	0
nursesched-sprint02	142.25	370	142.08	0.999	370	1.000	0	0	0
	85.40	409	85.18	0.997	409	1.000	0	0	0
	67.56	222	67.71	1.002	222	1.000	0	0	0
nw04	38.01	6	37.93	0.998	6	1.000	0	0	0
	31.46	5	31.39	0.998	5	1.000	0	0	0
	35.17	6	35.16	1.000	6	1.000	0	0	0
opm2-z10-s4	24.70%	997	24.70%	1.000	1000	1.003	0	0	0
	27.76%	584	27.76%	1.000	586	1.003	0	0	0
	26.96%	1015	26.96%	1.000	1015	1.000	0	0	0
p200x1188c	3.55	2	3.53	0.994	2	1.000	0	0	0
	3.96	3	3.96	1.000	3	1.000	0	0	0
	3.57	2	3.62	1.014	2	1.000	0	0	0
peg-solitaire-a3	∞	5756	∞	1.000	5752	0.999	0	0	0
	∞	3578	∞	1.000	3557	0.994	0	0	0

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
	∞	3962	∞	1.000	3969	1.002	0	0	0
pg5_34	1151.97	139447	1173.22	1.018	148717	*1.066*	20081	3853057	0
	1522.31	172430	1134.07	**0.745**	144543	**0.838**	31619	4252733	0
	994.39	128293	1085.15	*1.091*	121673	**0.948**	31923	3326334	0
pg	99.44	2781	101.85	1.024	2687	0.966	628	136418	0
	80.58	794	86.23	*1.070*	1372	*1.728*	585	102074	0
	88.23	848	107.44	*1.218*	2311	*2.725*	1063	182388	0
physicianshed3-3	∞	415	∞	1.000	415	1.000	0	0	0
	∞	313	∞	1.000	313	1.000	0	0	0
	∞	361	∞	1.000	361	1.000	0	0	0
physicianshed6-2	124.88	377	124.81	0.999	377	1.000	0	0	0
	465.94	2804	462.02	0.992	2804	1.000	0	0	0
	44.79	1	44.74	0.999	1	1.000	0	0	0
piperout-08	515.83	71	797.03	*1.545*	130	*1.831*	1010	2509	19
	659.36	1079	606.54	**0.920**	552	**0.512**	433	680	0
	1256.04	962	923.85	**0.736**	596	**0.620**	257	364	39
piperout-27	141.24	2	140.11	0.992	2	1.000	0	0	0
	271.59	566	275.91	1.016	566	1.000	15	40	0
	236.88	87	332.32	*1.403*	72	**0.828**	68	117	0
pk1	107.24	301100	107.55	1.003	301100	1.000	0	0	0
	109.48	317026	109.16	0.997	317026	1.000	0	0	0
	112.59	328715	112.34	0.998	328715	1.000	0	0	0
proteindesign121hz512p9	9.62%	571	9.60%	1.000	591	1.035	134	275	0
	11.98%	443	7.94%	1.000	440	0.993	52	58	0
	26.01%	603	26.02%	1.000	593	0.983	18	28	0
proteindesign122trx11p8	1.99%	2	1.95%	1.000	3	1.500	36	41	0
	1.92%	2	1.91%	1.000	8	4.000	92	111	0
	1.93%	17	1.93%	1.000	17	1.000	143	202	0
qap10	87.97	3	87.99	1.000	3	1.000	0	0	0
	111.85	5	111.82	1.000	5	1.000	0	0	0
	197.59	15	197.87	1.001	15	1.000	0	0	0
radiationm18-12-05	12.98%	412813	12.99%	1.000	479812	1.162	8460	27217	1073
	14.84%	533800	0.05%	1.000	750150	1.405	14094	39121	1726
	5.57%	751483	1.89%	1.000	551080	0.733	8455	26581	1531
radiationm40-10-02	62.90%	99496	67.02%	1.000	53316	0.536	1110	3484	213
	24.75%	95368	57.74%	1.000	27109	0.284	1725	8522	421
	43.31%	85305	22.69%	1.000	99008	1.161	3380	17079	453
rail01	2.74%	205	2.74%	1.000	200	0.976	0	0	0
	25.21%	182	25.21%	1.000	182	1.000	0	0	0
	7.32%	183	7.32%	1.000	183	1.000	0	0	0
rail02	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
rail507	157.07	623	156.67	0.997	623	1.000	0	0	0
	177.68	783	180.04	1.013	783	1.000	0	0	0
	194.14	771	193.43	0.996	771	1.000	0	0	0
ran14x18-disj-8	1872.99	682276	2109.62	*1.126*	656920	0.963	46693	824935	3
	1372.27	416671	1785.31	*1.301*	564900	*1.356*	45871	749904	5
	2082.12	785350	1694.59	**0.814**	593570	**0.756**	44838	749522	5
rd-rplusc-21	≥ 10000%	422103	≥ 10000%	1.000	484631	1.148	3413	3721	0
	≥ 10000%	501179	≥ 10000%	1.000	737139	1.471	6536	7402	0
	≥ 10000%	639178	≥ 10000%	1.000	763715	1.195	2948	3340	1
reblock115	5110.88	779543	4390.48	**0.859**	704168	**0.903**	0	0	0
	5854.84	786695	6605.46	*1.128*	882785	*1.122*	0	0	0
	4579.73	661438	5894.68	*1.287*	832788	*1.259*	0	0	0
rmatr100-p10	166.64	809	166.48	0.999	809	1.000	0	0	0

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
	163.04	822	162.84	0.999	822	1.000	0	0	0
	160.71	827	160.62	0.999	827	1.000	0	0	0
rmatr200-p5	22.40%	423	22.40%	1.000	421	0.995	0	0	0
	22.02%	421	19.56%	1.000	423	1.005	0	0	0
	21.08%	393	21.08%	1.000	403	1.025	0	0	0
rocI-4-11	636.15	12127	638.21	1.003	12970	*1.070*	96	656	11
	890.92	15544	1001.80	*1.124*	17602	*1.132*	159	956	7
	480.74	8974	498.07	1.036	9550	*1.064*	144	875	6
rocII-5-11	153.95%	3381	108.52%	1.000	3399	1.005	165	235	0
	155.01%	2626	109.87%	1.000	2764	1.053	160	231	0
	109.27%	2695	109.11%	1.000	2522	0.936	97	116	0
rococoB10-011000	13.69%	151830	13.71%	1.000	151103	0.995	0	0	0
	15.08%	143682	15.09%	1.000	143253	0.997	0	0	0
	12.80%	153757	12.80%	1.000	153839	1.001	0	0	0
rococoC10-001000	770.61	53303	765.76	0.994	53303	1.000	0	0	0
	851.05	63090	851.99	1.001	63090	1.000	0	0	0
	1629.78	162527	1626.91	0.998	162527	1.000	0	0	0
roi2alpha3n4	1425.48	12529	1424.80	1.000	12529	1.000	0	0	0
	1941.34	17446	1940.46	1.000	17446	1.000	0	0	0
	1490.05	13303	1486.54	0.998	13303	1.000	0	0	0
roi5alpha10n8	35.37%	6022	35.37%	1.000	5989	0.995	0	0	0
	40.38%	6261	40.36%	1.000	6346	1.014	0	0	0
	32.14%	6789	32.14%	1.000	6789	1.000	0	0	0
roll3000	36.69	1986	36.86	1.005	1986	1.000	539	1438	14
	55.83	3453	38.91	**0.697**	2149	**0.622**	642	2465	68
	37.30	2319	60.26	*1.616*	3736	*1.611*	1155	3483	31
s100	14.04%	18	5.53%	1.000	20	1.111	0	0	0
	29.84%	17	29.84%	1.000	17	1.000	0	0	0
	1.06%	22	1.06%	1.000	22	1.000	0	0	0
s250r10	0.28%	23082	0.28%	1.000	22897	0.992	0	0	0
	6324.93	45426	6366.45	1.007	45426	1.000	0	0	0
	0.23%	31934	0.23%	1.000	31811	0.996	0	0	0
satellites2-40	∞	19	∞	1.000	19	1.000	1	1	0
	∞	4	∞	1.000	4	1.000	0	0	0
	70.59%	33	70.59%	1.000	33	1.000	2	2	0
satellites2-60-fs	∞	33	∞	1.000	33	1.000	1	1	0
	∞	137	∞	1.000	137	1.000	18	18	0
	∞	28	∞	1.000	28	1.000	1	1	0
savsched1	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
sct2	0.03%	626617	0.03%	1.000	600226	0.958	9604	114239	6447
	0.05%	555785	0.05%	1.000	659682	1.187	10379	205028	3020
	0.03%	1529359	0.03%	1.000	994927	0.651	12226	162541	7626
seymour1	73.25	1554	90.45	*1.235*	1627	1.047	85	235	3
	69.25	1466	67.90	0.981	1466	1.000	67	147	3
	71.80	1822	72.05	1.003	1822	1.000	100	224	3
seymour	0.66%	242183	0.66%	1.000	242500	1.001	0	0	0
	0.68%	221519	0.68%	1.000	222209	1.003	0	0	0
	0.74%	225942	0.74%	1.000	225373	0.997	0	0	0
sing326	0.30%	8603	0.15%	1.000	11755	1.366	933	1132189	87
	0.15%	8634	0.17%	1.000	8196	0.949	851	996582	17
	0.14%	9576	0.32%	1.000	7997	0.835	1405	1673762	17
sing44	0.45%	5586	0.45%	1.000	5531	0.990	422	163964	0
	0.19%	7471	0.19%	1.000	7349	0.984	661	583858	0
	0.26%	2798	0.27%	1.000	2267	0.810	560	631983	1

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
snp-02-004-104	0.00%	15367	0.00%	1.000	14561	0.948	1880	27689	0
	0.00%	13656	0.00%	1.000	18040	1.321	1712	29797	0
	0.00%	20392	0.00%	1.000	19680	0.965	1431	24076	0
sorrell3	43.81%	41058	43.81%	1.000	41208	1.004	0	0	0
	35.59%	39358	35.59%	1.000	39514	1.004	0	0	0
	19.11%	8959	19.11%	1.000	8801	0.982	0	0	0
sp150x300d	3.96	3472	3.96	1.000	3472	1.000	164	355	91
	3.12	2569	3.12	1.000	2569	1.000	85	334	5
	1.32	848	1.29	0.977	848	1.000	43	124	2
sp97ar	0.98%	15764	0.98%	1.000	15747	0.999	0	0	0
	1.02%	22814	1.02%	1.000	22961	1.006	0	0	0
	1.53%	24818	1.53%	1.000	24828	1.000	0	0	0
sp98ar	1.43%	71712	1.43%	1.000	71746	1.000	0	0	0
	0.48%	66738	0.48%	1.000	67060	1.005	0	0	0
	0.98%	71775	0.98%	1.000	71271	0.993	0	0	0
splice1k1	309.20%	514	309.20%	1.000	513	0.998	0	0	0
	376.10%	596	376.10%	1.000	594	0.997	0	0	0
	358.74%	837	358.74%	1.000	834	0.996	0	0	0
square41	109.98%	30	109.98%	1.000	30	1.000	5	10	0
	89.32%	38	89.32%	1.000	37	0.974	25	61	0
	92.32%	27	92.32%	1.000	28	1.037	1	4	0
square47	231.21%	4	231.21%	1.000	4	1.000	0	0	0
	117.00%	13	117.00%	1.000	13	1.000	8	35	0
	231.21%	1	231.21%	1.000	1	1.000	0	0	0
supportcase10	803.51%	1	803.51%	1.000	1	1.000	0	0	0
	989.07%	1	989.07%	1.000	1	1.000	0	0	0
	1054.36%	1	1054.36%	1.000	1	1.000	0	0	0
supportcase12	1.31%	1473	1.31%	1.000	1463	0.993	0	0	0
	1.35%	2292	1.35%	1.000	2297	1.002	0	0	0
	1.16%	1772	1.30%	1.000	1505	0.849	0	0	0
supportcase18	3.84%	419796	3.84%	1.000	419350	0.999	0	0	0
	5.96%	236635	5.96%	1.000	237591	1.004	0	0	0
	3.84%	198642	3.84%	1.000	198815	1.001	0	0	0
supportcase19	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
	∞	1	∞	1.000	1	1.000	0	0	0
supportcase22	∞	51	∞	1.000	51	1.000	0	0	0
	∞	18	∞	1.000	18	1.000	0	0	0
	∞	66	∞	1.000	66	1.000	0	0	0
supportcase26	9.03%	8673498	8.94%	1.000	8135621	0.938	73790	151824	42
	3841.51	5550476	5238.22	*1.364*	6761735	*1.218*	42236	84405	1
	6080.50	7794727	4487.28	**0.738**	5497025	**0.705**	53692	110623	3
supportcase33	1500.01	11787	1598.38	*1.066*	12756	*1.082*	537	558	0
	3162.80	24151	1600.98	**0.506**	7176	**0.297**	378	398	0
	1337.69	7556	682.16	**0.510**	3786	**0.501**	493	518	0
supportcase40	788.54	6258	786.50	0.997	6335	1.012	3743	337428	0
	1223.53	11722	946.94	**0.774**	7991	**0.682**	3507	313703	0
	803.81	6970	797.74	0.992	6970	1.000	3421	289071	0
supportcase42	0.14%	464240	0.38%	1.000	305571	0.658	0	0	0
	0.13%	547707	0.10%	1.000	380155	0.694	0	0	0
	0.28%	258072	0.35%	1.000	467610	1.812	7	7	0
supportcase6	9.13%	19201	9.13%	1.000	18980	0.988	0	0	0
	8.41%	17726	8.41%	1.000	17726	1.000	0	0	0
	9.72%	17624	9.72%	1.000	17709	1.005	0	0	0
supportcase7	180.82	59	179.98	0.995	59	1.000	31	9612	0
	193.14	47	193.62	1.002	45	0.957	74	40227	0

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Table A.3: Detailed computational results on MIPLIB 2017 benchmark with and without variable bound constraint substitution.

	vbound-cancellation disabled		combined						
Instance	T	N	T	T_Q	N	N_Q	#VBC	cVBC	dVBC
	208.73	32	210.25	1.007	32	1.000	110	53430	0
swath1	22.03	438	21.09	0.957	281	**0.642**	920	47380	8
	16.68	227	17.34	1.040	245	*1.079*	734	34806	3
	18.37	266	19.82	*1.079*	292	*1.098*	877	44868	3
swath3	242.86	33006	226.20	**0.931**	28316	**0.858**	7278	384774	27
	180.43	21033	182.91	1.014	21837	1.038	6664	349970	22
	417.85	70960	427.45	1.023	74192	1.046	13631	680849	110
tbfp-network	2323.97	574	2356.81	1.014	574	1.000	0	0	0
	1683.53	71	1683.80	1.000	71	1.000	0	0	0
	1088.02	99	1088.57	1.001	99	1.000	0	0	0
thor50dday	23.30%	95	23.30%	1.000	95	1.000	7	970	0
	21.49%	11	21.49%	1.000	12	1.091	1	93	0
	14.80%	34	14.80%	1.000	34	1.000	0	0	0
timtab1	68.29	57181	73.73	*1.080*	64175	*1.122*	4716	36866	894
	73.22	55234	67.90	**0.927**	51540	**0.933**	3310	25860	474
	76.52	60784	70.92	**0.927**	55054	**0.906**	4993	39870	964
tr12-30	864.04	604848	606.97	**0.702**	423661	**0.700**	27858	133842	0
	708.84	522569	650.32	**0.917**	475420	**0.910**	35144	103546	70
	516.81	295635	397.52	**0.769**	213946	**0.724**	19017	155457	0
traininstance2	∞	50327	∞	1.000	67099	1.333	708	919	1
	∞	40455	∞	1.000	52063	1.287	1261	1759	13
	$\geq$ 10000%	55987	6286.13%	1.000	73138	1.306	600	737	15
traininstance6	794.97%	405190	634.16%	1.000	456248	1.126	3860	5136	58
	655.46%	320501	626.92%	1.000	347529	1.084	5435	7060	66
	576.79%	324532	520.12%	1.000	454368	1.400	7637	10460	52
trento1	0.07%	58586	0.07%	1.000	57766	0.986	11	13	0
	0.07%	61566	0.10%	1.000	51033	0.829	6	9	0
	0.09%	51991	1.67%	1.000	35013	0.673	7	9	0
triptim1	1098.59	8	1099.43	1.001	8	1.000	0	0	0
	747.80	7	747.73	1.000	7	1.000	0	0	0
	1061.53	8	1065.09	1.003	8	1.000	0	0	0
uccase12	0.00%	78983	0.00%	1.000	77800	0.985	1786	20788	401
	0.00%	87529	0.00%	1.000	91468	1.045	1908	25777	296
	0.00%	88050	0.00%	1.000	98605	1.120	1329	12004	336
uccase9	1.51%	408	1.98%	1.000	498	1.221	186	148817	0
	2.05%	1099	1.48%	1.000	1166	1.061	163	124154	0
	6.85%	1274	2.82%	1.000	550	0.432	151	126318	0
uct-subprob	1111.65	44339	1102.62	0.992	44339	1.000	0	0	0
	1634.73	59559	1631.60	0.998	59559	1.000	0	0	0
	2514.17	95674	2506.36	0.997	95674	1.000	0	0	0
unitcal_7	267.83	89	272.59	1.018	89	1.000	118	6578	0
	296.79	176	298.12	1.004	180	1.023	282	68304	0
	384.88	436	387.18	1.006	436	1.000	231	66533	0
var-smallemery-m6j6	0.81%	615295	0.93%	1.000	568323	0.924	0	0	0
	0.87%	658145	0.87%	1.000	656232	0.997	0	0	0
	6693.63	683202	6729.45	1.005	683202	1.000	0	0	0
wachplan	2341.48	219938	2340.84	1.000	219938	1.000	0	0	0
	3644.81	333384	3419.67	**0.938**	302179	**0.906**	0	0	0
	2345.88	198054	2343.95	0.999	198054	1.000	0	0	0

Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
30n20b8	149.78	171	149.68	0.999	171	1.000	3	0
	773.41	2674	623.60	**0.806**	1999	**0.748**	5	36
	474.09	3834	693.56	*1.463*	3499	**0.913**	6	76
50v-10	1.36%	860023	1.69%	1.000	829421	0.964	27	2
	1.38%	977162	1.15%	1.000	867997	0.888	28	4
	1.42%	1024944	1.37%	1.000	833134	0.813	30	2
CMS750_4	173.21	2061	185.73	*1.072*	2028	0.984	10	52
	532.83	9672	370.72	**0.696**	3254	**0.336**	8	112
	372.77	9265	473.12	*1.269*	13518	*1.459*	8	133
academictimetablesmall	∞	2317	∞	1.000	2315	0.999	1	0
	∞	3512	∞	1.000	3505	0.998	11	0
	∞	2681	∞	1.000	2681	1.000	2	0
air05	40.26	648	40.07	0.995	648	1.000	24	62
	36.13	716	36.54	1.011	716	1.000	32	90
	31.36	282	30.22	0.964	282	1.000	8	18
app1-1	3.50	2	3.53	1.009	2	1.000	2	0
	4.88	3	4.94	1.012	3	1.000	2	15
	4.16	6	4.17	1.002	6	1.000	2	14
app1-2	643.47	33	642.80	0.999	33	1.000	2	0
	791.07	20	789.47	0.998	20	1.000	2	6
	616.82	20	618.36	1.002	20	1.000	2	0
assign1-5-8	4.73%	6050427	4.74%	1.000	5736357	0.948	4	9
	4.54%	6084457	4.54%	1.000	6813236	1.120	7	73
	5.04%	6173436	4.80%	1.000	6333262	1.026	9	63
atlanta-ip	3.60%	18545	3.60%	1.000	18533	0.999	130	0
	3.78%	21656	3.81%	1.000	21153	0.977	16	0
	4.27%	30914	4.27%	1.000	30903	1.000	32	0
b1c1s1	16.77%	44740	17.13%	1.000	35962	0.804	35	1195
	17.31%	17207	18.36%	1.000	21112	1.227	30	810
	18.01%	19831	17.69%	1.000	18673	0.942	27	596
bab2	1.29%	3473	1.29%	1.000	3473	1.000	7	0
	1.10%	3384	2.44%	1.000	3262	0.964	5	0
	∞	1981	∞	1.000	1981	1.000	0	0
bab6	0.58%	4937	0.58%	1.000	4790	0.970	10	0
	0.83%	3277	1.14%	1.000	3258	0.994	4	0
	1.94%	4745	1.94%	1.000	4779	1.007	7	0
beasleyC3	31.50	83	31.56	1.002	83	1.000	5	1
	17.47	2	17.35	0.993	2	1.000	6	2
	48.04	432	47.20	0.983	453	1.049	8	72
binkar10_1	33.75	2544	31.34	**0.929**	2560	1.006	7	207
	30.29	2325	29.22	0.965	2246	0.966	6	218
	31.18	2376	28.71	**0.921**	2509	*1.056*	11	344
blp-ar98	0.30%	231185	0.27%	1.000	238231	1.030	28	6
	0.30%	224114	0.33%	1.000	207500	0.926	39	4
	0.27%	240188	0.32%	1.000	229423	0.955	51	4
blp-ic98	2.79%	289253	1.38%	1.000	304769	1.054	29	13
	1.20%	282117	2.41%	1.000	254061	0.901	24	17
	1.59%	296470	2.11%	1.000	278188	0.938	27	8
bnatt400	973.43	6821	970.91	0.997	6821	1.000	1	0
	1102.38	6346	1105.02	1.002	6346	1.000	1	0
	745.47	5500	745.15	1.000	5500	1.000	1	0
bnatt500	4382.63	29526	4368.17	0.997	29526	1.000	0	0
	6339.53	38962	6333.06	0.999	38962	1.000	0	0
	4987.35	29029	4996.90	1.002	29029	1.000	0	0
bppc4-08	1.92%	793025	1.92%	1.000	797503	1.006	16	117

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
	1.92%	758030	1.92%	1.000	938927	1.239	17	100
	1.92%	867081	1.92%	1.000	793397	0.915	17	153
brazil3	3363.61	2570	3360.46	0.999	2570	1.000	11	1
	4255.56	2347	4252.19	0.999	2347	1.000	8	2
	3826.38	3357	3785.08	0.989	3302	0.984	5	2
buildingenergy	0.13%	96	0.13%	1.000	96	1.000	3	0
	0.15%	85	0.15%	1.000	85	1.000	4	0
	0.13%	12	0.13%	1.000	12	1.000	3	0
cbs-cta	40.14	1	40.27	1.003	1	1.000	3	0
	315.38	31	314.10	0.996	31	1.000	3	0
	35.38	1	35.77	1.011	1	1.000	3	0
chromaticindex1024-7	33.33%	964	33.33%	1.000	964	1.000	1	0
	33.33%	1155	33.33%	1.000	1171	1.014	1	0
	6365.47	757	6429.72	1.010	757	1.000	1	0
chromaticindex512-7	1187.48	361	1172.37	0.987	361	1.000	1	0
	3708.09	3133	3689.97	0.995	3133	1.000	1	0
	33.33%	40438	33.33%	1.000	40579	1.003	1	0
cmflsp50-24-8-8	4.18%	35061	3.98%	1.000	36090	1.029	11	70
	0.61%	62731	1.99%	1.000	85475	1.363	8	403
	3.37%	44705	4.86%	1.000	37790	0.845	5	96
co-100	1.75%	54134	1.74%	1.000	54008	0.998	53	85
	29.30%	16731	91.77%	1.000	7012	0.419	20	64
	53.41%	6553	3.18%	1.000	10565	1.612	36	163
cod105	47.86%	7036	47.57%	1.000	7261	1.032	4	4
	47.98%	6632	48.00%	1.000	6829	1.030	5	6
	48.06%	6622	48.07%	1.000	6601	0.997	4	4
comp07-2idx	966.67%	4001	966.67%	1.000	3996	0.999	16	0
	2800.00%	744	2800.00%	1.000	743	0.999	7	0
	1716.67%	1440	1716.67%	1.000	1449	1.006	6	0
comp21-2idx	247.37%	10996	247.43%	1.000	10931	0.994	13	0
	195.50%	9836	195.50%	1.000	9835	1.000	23	0
	248.72%	11698	248.72%	1.000	11711	1.001	17	0
cost266-UUE	5113.69	369616	4923.15	0.963	375684	1.016	50	1885
	4355.08	351526	3728.83	**0.856**	294630	**0.838**	45	1721
	5036.66	371569	4067.72	**0.808**	306702	**0.825**	35	1319
cryptanalysiskb128n5obj14	∞	110	∞	1.000	110	1.000	0	0
	∞	56	∞	1.000	59	1.054	0	0
	∞	90	∞	1.000	90	1.000	0	0
cryptanalysiskb128n5obj16	∞	105	∞	1.000	104	0.990	0	0
	2795.28	37	2790.65	0.998	37	1.000	1	0
	∞	96	∞	1.000	97	1.010	0	0
csched007	2900.82	240564	2327.77	**0.802**	187288	**0.779**	25	2
	3154.88	277315	2613.95	**0.829**	220934	**0.797**	22	2
	2678.68	234286	3393.08	*1.267*	247755	*1.057*	16	5
csched008	2.91%	606571	2.81%	1.000	455870	0.752	9	75
	7127.81	931841	2.33%	1.010	694455	0.745	9	21
	2381.21	228445	5772.95	*2.424*	546382	*2.392*	9	41
cvs16r128-89	22.58%	107264	23.28%	1.000	67980	0.634	11	141
	25.13%	25750	22.61%	1.000	34973	1.358	20	160
	20.85%	49613	23.01%	1.000	47219	0.952	13	174
dano3_3	143.45	10	143.70	1.002	10	1.000	6	1
	142.21	14	142.65	1.003	14	1.000	4	0
	125.10	17	124.56	0.996	17	1.000	5	2
dano3_5	638.30	276	635.04	0.995	276	1.000	6	22
	283.74	166	285.81	1.007	159	0.958	6	49
	284.61	140	285.94	1.005	140	1.000	5	16

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
decomp2	2.45	1	2.39	0.976	1	1.000	1	0
	2.46	1	2.42	0.984	1	1.000	2	0
	2.48	1	2.50	1.008	1	1.000	1	0
drayage-100-23	16.50	32	16.43	0.996	32	1.000	4	0
	19.56	48	19.52	0.998	48	1.000	4	0
	13.43	16	13.50	1.005	16	1.000	3	0
drayage-25-23	0.07%	720400	0.07%	1.000	720814	1.001	10	0
	0.07%	792532	0.07%	1.000	790871	0.998	12	0
	6925.29	552534	6941.84	1.002	552534	1.000	14	0
dws008-01	44.37%	143681	44.84%	1.000	144766	1.008	4	162
	43.13%	142800	44.28%	1.000	157395	1.102	10	353
	53.94%	151056	52.63%	1.000	153108	1.014	29	650
eil33-2	78.78	561	81.20	1.031	343	**0.611**	13	430
	78.80	561	101.92	*1.293*	395	**0.704**	15	452
	64.23	613	105.72	*1.646*	541	**0.883**	6	85
eilA101-2	8.90%	11021	20.05%	1.000	11110	1.008	28	390
	13.47%	11503	13.20%	1.000	12688	1.103	16	313
	17.64%	12058	13.37%	1.000	13480	1.118	17	305
enlight_hard	0.50	1	0.50	1.000	1	1.000	1	0
	0.50	1	0.50	1.000	1	1.000	1	0
	0.50	1	0.50	1.000	1	1.000	1	0
ex10	493.43	1	493.80	1.001	1	1.000	1	0
	499.89	1	497.94	0.996	1	1.000	1	0
	576.48	1	581.12	1.008	1	1.000	1	0
ex9	28.57	1	27.98	0.979	1	1.000	1	0
	26.88	1	27.30	1.016	1	1.000	1	0
	27.26	1	27.02	0.991	1	1.000	1	0
exp-1-500-5-5	2.28	1	2.28	1.000	1	1.000	7	1
	2.23	1	2.22	0.996	1	1.000	3	1
	2.23	1	2.21	0.991	1	1.000	3	1
fast0507	305.46	1377	322.23	*1.055*	1284	**0.932**	8	11
	180.55	789	280.17	*1.552*	1223	*1.550*	8	9
	249.56	1054	365.44	*1.464*	1711	*1.623*	8	10
fastxgemm-n2r6s0t2	4634.71	1091678	4702.82	1.015	1118937	1.025	5	103
	1847.11	404965	4017.11	*2.175*	1012967	*2.501*	6	233
	5106.21	1218045	3129.08	**0.613**	769500	**0.632**	7	291
fhnw-binpack4-48	∞	4043398	∞	1.000	4040499	0.999	0	0
	∞	3528303	∞	1.000	3525851	0.999	0	0
	∞	3412684	∞	1.000	3413924	1.000	0	0
fhnw-binpack4-4	∞	14866266	∞	1.000	14733968	0.991	0	0
	∞	14002290	∞	1.000	13981261	0.998	0	0
	∞	11625787	∞	1.000	11607995	0.998	0	0
fiball	534.20	5059	465.55	**0.871**	4111	**0.813**	8	1
	423.45	3216	447.14	*1.056*	3521	*1.095*	8	6
	579.49	5313	499.03	**0.861**	5672	*1.068*	8	50
gen-ip002	1399.45	6075461	1315.68	**0.940**	5856334	0.964	22	552
	1305.34	5725874	1295.56	0.993	5478569	0.957	19	477
	1375.26	5885796	1271.92	**0.925**	5583912	**0.949**	19	518
gen-ip054	3344.49	16710950	3047.64	**0.911**	15245360	**0.912**	21	733
	2452.64	12245498	2530.93	1.032	12476019	1.019	23	1009
	4133.81	20348199	3381.24	**0.818**	16438070	**0.808**	27	864
germanrr	1.46%	3402	1.46%	1.000	3418	1.005	3	0
	2.11%	2852	2.11%	1.000	2851	1.000	7	0
	1.94%	3527	1.94%	1.000	3559	1.009	8	0
gfd-schedulen180f7d50m30k18	∞	4	∞	1.000	4	1.000	0	0
	∞	8	∞	1.000	8	1.000	0	0

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
	∞	10	∞	1.000	10	1.000	0	0
glass-sc	2651.11	241329	2655.26	1.002	241329	1.000	5	15
	3208.66	289206	3214.67	1.002	289206	1.000	5	14
	2820.59	251112	2819.06	0.999	251112	1.000	5	0
glass4	3197.72	2512983	4008.75	*1.254*	2705421	*1.077*	38	966
	2281.42	2101434	2392.84	1.049	1888717	**0.899**	44	953
	2001.07	1508903	2212.84	*1.106*	1599046	*1.060*	40	660
gmu-35-40	0.04%	2454791	0.05%	1.000	2051936	0.836	13	2
	0.04%	3192925	0.03%	1.000	2099939	0.658	16	2
	0.02%	2471843	0.03%	1.000	1381092	0.559	14	2
gmu-35-50	0.05%	1058467	0.02%	1.000	1317781	1.245	24	2
	0.04%	1089662	0.03%	1.000	1247342	1.145	28	2
	0.02%	1100457	0.04%	1.000	1016723	0.924	17	2
graph20-20-1rand	165.64%	17122	163.73%	1.000	6171	0.360	8	9
	163.77%	12599	165.38%	1.000	8277	0.657	4	3
	170.23%	7147	172.66%	1.000	7513	1.051	6	5
graphdraw-domain	844.42	1611437	1010.47	*1.197*	1823083	*1.131*	34	1967
	1195.65	2105392	1122.85	**0.939**	1941578	**0.922**	30	1906
	1739.95	2981841	1664.67	0.957	2907888	0.975	53	3429
h80x6320d	69.85	4	69.54	0.996	4	1.000	4	0
	86.37	10	86.17	0.998	10	1.000	8	0
	86.44	5	86.62	1.002	5	1.000	4	0
highschool1-aigio	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
hypothyroid-k1	19.86	1	20.04	1.009	1	1.000	3	6
	19.89	1	19.99	1.005	1	1.000	3	6
	19.98	1	20.16	1.009	1	1.000	3	6
ic97_potential	0.76%	7683335	0.84%	1.000	7214792	0.939	53	2599
	0.55%	5887400	0.75%	1.000	6107856	1.037	42	1745
	0.67%	7649850	0.86%	1.000	7579116	0.991	44	2364
icir97_tension	6649.86	2386444	0.07%	1.083	3185773	1.335	23	618
	0.07%	3173604	0.05%	1.000	2776552	0.875	12	433
	0.09%	2964514	0.08%	1.000	2729235	0.921	18	591
irish-electricity	∞	93	∞	1.000	93	1.000	0	0
	18.60%	1306	18.43%	1.000	1317	1.008	5	24
	∞	1333	∞	1.000	1333	1.000	0	0
irp	12.33	6	12.51	1.015	6	1.000	6	3
	11.95	4	12.05	1.008	4	1.000	6	3
	12.47	5	12.58	1.009	5	1.000	6	3
istanbul-no-cutoff	151.14	341	154.02	1.019	347	1.018	8	189
	165.39	269	166.34	1.006	245	**0.911**	4	63
	291.78	481	285.14	0.977	475	0.988	9	154
k1mushroom	1879.06	7	1897.56	1.010	7	1.000	4	4
	1577.48	11	1583.93	1.004	11	1.000	7	11
	1303.96	3	1321.29	1.013	3	1.000	3	2
lectsched-5-obj	146.67%	159156	166.67%	1.000	148725	0.934	9	143
	153.33%	138540	120.00%	1.000	130812	0.944	28	442
	126.67%	66813	126.67%	1.000	64923	0.972	11	169
leo1	6.60%	82988	6.11%	1.000	80819	0.974	34	35
	7.00%	71808	7.14%	1.000	34905	0.486	16	39
	7.29%	57961	7.53%	1.000	45969	0.793	17	22
leo2	∞	91966	∞	1.000	101616	1.105	18	18
	∞	121421	∞	1.000	110967	0.914	11	16
	∞	110548	∞	1.000	146706	1.327	19	30
lotsize	0.64%	15336	0.67%	1.000	16786	1.095	12	689

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
	0.91%	24653	0.88%	1.000	20493	0.831	12	737
	0.64%	18045	0.70%	1.000	17911	0.993	19	892
mad	∞	13053639	∞	1.000	8295624	0.636	35	133
	∞	17417457	∞	1.000	14934806	0.857	30	86
	∞	11042944	∞	1.000	15381075	1.393	34	150
map10	995.07	1494	1006.71	1.012	1637	*1.096*	13	311
	675.54	768	633.84	**0.938**	724	**0.943**	9	159
	830.50	955	792.96	0.955	965	1.010	10	253
map16715-04	2177.21	1961	2158.43	0.991	1933	0.986	7	221
	2434.77	2281	2335.51	0.959	2173	0.953	6	215
	2080.59	1982	2160.04	1.038	1990	1.004	7	356
markshare2	∞	5338861	∞	1.000	5827069	1.091	20	204
	∞	6726451	∞	1.000	5581862	0.830	21	240
	∞	5463573	∞	1.000	5052479	0.925	26	286
markshare_4_0	342.25	2928397	72.47	**0.212**	612396	**0.209**	17	475
	307.25	2661583	70.48	**0.229**	589762	**0.222**	14	399
	260.24	2235991	85.88	**0.330**	719508	**0.322**	16	467
mas74	1696.01	5115429	1680.79	0.991	4932223	0.964	10	77
	2206.78	8092045	2282.09	1.034	7992914	0.988	5	71
	1302.75	3949864	1563.59	*1.200*	4674399	*1.183*	9	80
mas76	140.01	420665	136.88	0.978	406104	0.965	6	75
	167.53	525538	168.46	1.006	525538	1.000	5	0
	150.34	450422	152.65	1.015	450422	1.000	5	0
mc11	142.22	5552	149.40	*1.050*	6484	*1.168*	10	375
	102.84	3115	80.39	**0.782**	1411	**0.453**	10	253
	94.23	2184	106.11	*1.126*	3386	*1.550*	7	150
mcsched	358.30	15011	318.21	**0.888**	11378	**0.758**	9	297
	234.81	9846	235.33	1.002	9846	1.000	17	662
	298.88	10929	306.32	1.025	12017	*1.100*	22	634
mik-250-20-75-4	53.03	23893	52.78	0.995	23893	1.000	11	0
	43.71	15175	43.96	1.006	15175	1.000	11	0
	52.33	20733	52.36	1.001	20733	1.000	11	0
milo-v12-6-r2-40-1	10.59%	212864	9.47%	1.000	189681	0.891	17	12
	7.61%	320341	8.96%	1.000	323326	1.009	17	17
	11.47%	384685	11.33%	1.000	417232	1.085	12	16
momentum1	6.01%	153736	24.76%	1.000	94037	0.612	15	79
	7.74%	100854	7.36%	1.000	91471	0.907	58	28
	6.80%	210209	6.53%	1.000	188055	0.895	81	456
mushroom-best	871.57	47519	579.50	**0.665**	27393	**0.576**	9	21
	134.13%	94492	134.09%	1.000	94624	1.001	10	0
	122.00%	98582	121.97%	1.000	98893	1.003	14	0
mzzv11	209.76	484	210.71	1.005	484	1.000	8	2
	263.27	987	263.08	0.999	987	1.000	15	2
	196.39	616	195.89	0.997	616	1.000	7	0
mzzv42z	170.76	366	175.26	1.026	415	*1.134*	26	17
	244.76	712	246.00	1.005	712	1.000	32	1
	307.27	719	306.34	0.997	719	1.000	55	9
n2seq36q	927.84	5438	936.81	1.010	5438	1.000	20	1
	554.86	2560	1061.28	*1.913*	4712	*1.841*	22	1
	423.63	2461	1170.79	*2.764*	4632	*1.882*	17	3
n3div36	2.58%	216338	2.59%	1.000	213866	0.989	13	0
	2.87%	205084	2.86%	1.000	207136	1.010	18	0
	2.68%	207580	2.69%	1.000	202891	0.977	17	0
n5-3	28.06	1124	26.40	**0.941**	926	**0.824**	16	196
	28.38	1026	27.79	0.979	971	**0.946**	14	328
	25.67	1047	27.09	*1.055*	1087	1.038	23	147

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
neos-1122047	10.10	1	9.92	0.982	1	1.000	1	0
	9.64	1	9.76	1.012	1	1.000	1	0
	9.83	1	9.70	0.987	1	1.000	1	0
neos-1171448	57.94	101	58.11	1.003	101	1.000	13	7
	5.18	1	5.16	0.996	1	1.000	9	3
	51.08	86	51.55	1.009	86	1.000	11	3
neos-1171737	1.04%	3910	1.04%	1.000	3912	1.001	11	2
	1.56%	3991	1.56%	1.000	4009	1.005	13	0
	1.21%	12968	1.30%	1.000	11719	0.904	13	68
neos-1354092	∞	613	∞	1.000	613	1.000	0	0
	∞	824	∞	1.000	820	0.995	0	0
	∞	639	∞	1.000	639	1.000	0	0
neos-1445765	43.58	133	43.72	1.003	133	1.000	9	21
	44.46	141	44.19	0.994	141	1.000	7	15
	45.05	125	44.74	0.993	125	1.000	6	12
neos-1456979	7.49%	39937	7.49%	1.000	39961	1.001	15	0
	6.84%	38787	6.84%	1.000	38750	0.999	14	0
	7.29%	31530	7.29%	1.000	31540	1.000	11	0
neos-1582420	21.82	18	21.85	1.001	18	1.000	3	0
	10.91	9	10.92	1.001	9	1.000	3	0
	55.38	1381	55.49	1.002	1381	1.000	10	0
neos-2075418-temuka	6992.57	1	7024.05	1.005	1	1.000	0	0
	4534.31	1	4517.94	0.996	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-2657525-crna	∞	1304023	∞	1.000	3064132	2.350	7	49
	∞	3691411	∞	1.000	3681104	0.997	9	16
	∞	1979657	∞	1.000	2122332	1.072	3	10
neos-2746589-doon	0.47%	54848	0.46%	1.000	55681	1.015	4	0
	0.73%	30136	0.73%	1.000	30280	1.005	9	0
	0.11%	182671	0.11%	1.000	182349	0.998	6	0
neos-2978193-inde	0.50%	553211	0.50%	1.000	549249	0.993	3	0
	0.13%	580943	0.13%	1.000	573707	0.988	3	0
	0.50%	551656	0.50%	1.000	548119	0.994	3	0
neos-2987310-joes	17.52	1	17.49	0.998	1	1.000	3	0
	15.39	1	15.31	0.995	1	1.000	3	0
	13.79	1	13.67	0.991	1	1.000	3	0
neos-3004026-krka	53.23	2711	53.06	0.997	2711	1.000	1	0
	61.93	3485	62.47	1.009	3485	1.000	1	0
	46.80	1764	46.28	0.989	1764	1.000	1	0
neos-3024952-loue	6210.32	563456	4646.86	**0.748**	383076	**0.680**	18	687
	0.04%	663494	0.07%	1.000	688312	1.037	8	184
	0.04%	518511	0.04%	1.000	1114650	2.150	10	144
neos-3046615-murg	162.59%	7294477	169.81%	1.000	6971706	0.956	18	255
	161.31%	6839354	166.11%	1.000	6364063	0.931	22	290
	168.01%	6542495	163.66%	1.000	7613539	1.164	23	201
neos-3083819-nubu	12.84	2020	12.72	0.991	2020	1.000	18	0
	12.51	1578	12.37	0.989	1578	1.000	18	0
	20.72	3812	20.79	1.003	3812	1.000	13	0
neos-3216931-puriri	68.24%	9619	116.41%	1.000	5546	0.577	2	3
	151.50%	8053	5.50%	1.000	9705	1.205	4	2
	147.09%	4739	147.13%	1.000	4790	1.011	2	4
neos-3381206-awhea	1.19	1	1.18	0.992	1	1.000	6	0
	1.19	1	1.21	1.017	1	1.000	1	0
	1.23	1	1.20	0.976	1	1.000	2	0
neos-3402294-bobin	1966.80	10587	4386.37	*2.230*	40294	*3.806*	14	49
	1373.45	9979	618.95	**0.451**	3428	**0.344**	20	168

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
	636.11	1194	1620.92	*2.548*	9242	*7.740*	10	87
neos-3402454-bohle	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-3555904-turama	18.01%	146	18.01%	1.000	145	0.993	1	0
	∞	18	∞	1.000	18	1.000	0	0
	18.01%	16865	18.01%	1.000	16797	0.996	2	0
neos-3627168-kasai	0.12%	4335846	0.15%	1.000	4555684	1.051	50	1333
	0.08%	4565755	0.09%	1.000	4132791	0.905	56	1250
	0.33%	4670340	0.27%	1.000	5147129	1.102	33	978
neos-3656078-kumeu	∞	32	∞	1.000	32	1.000	0	0
	∞	82	∞	1.000	82	1.000	0	0
	∞	122	∞	1.000	122	1.000	0	0
neos-3754480-nidda	∞	19643977	∞	1.000	20000763	1.018	18	988
	∞	18575479	∞	1.000	18439214	0.993	16	850
	∞	19127316	∞	1.000	19108471	0.999	10	510
neos-3988577-wolgan	∞	311	∞	1.000	312	1.003	0	0
	∞	179	∞	1.000	179	1.000	0	0
	∞	439	∞	1.000	439	1.000	0	0
neos-4300652-rahue	438.74%	1351	431.97%	1.000	1365	1.010	5	0
	809.48%	1212	809.48%	1.000	1213	1.001	3	0
	316.83%	2128	316.83%	1.000	2127	1.000	10	0
neos-4338804-snowy	2.07%	4824212	1.66%	1.000	4875741	1.011	64	946
	1.66%	6401707	0.82%	1.000	6738902	1.053	87	861
	1.93%	5669262	1.66%	1.000	5067404	0.894	75	840
neos-4387871-tavua	11.43%	116247	11.39%	1.000	118375	1.018	11	0
	14.12%	116863	14.13%	1.000	116171	0.994	11	0
	18.62%	97491	18.66%	1.000	96695	0.992	9	0
neos-4413714-turia	297.22	2	299.23	1.007	2	1.000	11	0
	405.05	2	404.80	0.999	2	1.000	10	0
	278.04	2	277.10	0.997	2	1.000	13	0
neos-4532248-waihi	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-4647030-tutaki	0.01%	24542	0.01%	1.000	24413	0.995	3	10
	0.01%	23181	0.01%	1.000	22893	0.988	3	14
	0.01%	27226	0.01%	1.000	27292	1.002	3	0
neos-4722843-widden	1099.90	3196	2651.33	*2.411*	11357	*3.554*	12	123
	1359.60	4991	1033.65	**0.760**	3376	**0.676**	14	146
	1598.32	9232	1714.52	*1.073*	7919	**0.858**	14	231
neos-4738912-atrato	814.33	61981	813.40	0.999	61981	1.000	43	0
	2792.15	233679	3808.90	*1.364*	324992	*1.391*	37	12
	1786.70	209078	914.39	**0.512**	95736	**0.458**	26	1
neos-4763324-toguru	46.04%	8436	46.04%	1.000	8436	1.000	13	0
	45.08%	14925	45.08%	1.000	14962	1.002	17	0
	48.94%	7145	48.94%	1.000	7145	1.000	27	0
neos-4954672-berkel	9.33%	1070376	8.48%	1.000	1019990	0.953	35	1139
	9.91%	781488	8.71%	1.000	819107	1.048	44	1319
	8.33%	797459	8.00%	1.000	891993	1.119	33	1085
neos-5049753-cuanza	∞	52	∞	1.000	52	1.000	0	0
	15.39%	14	15.39%	1.000	14	1.000	1	0
	15.20%	12	15.20%	1.000	12	1.000	1	0
neos-5052403-cygnet	1.60%	113	1.60%	1.000	113	1.000	3	0
	1.38%	1	1.38%	1.000	1	1.000	3	0
	1.19%	63	1.19%	1.000	63	1.000	3	0
neos-5093327-huahum	9.83%	53063	10.32%	1.000	49854	0.940	20	707

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
	11.12%	50174	10.43%	1.000	52521	1.047	12	428
	8.66%	56149	12.17%	1.000	48532	0.864	10	368
neos-5104907-jarama	∞	8	∞	1.000	8	1.000	0	0
	∞	9	∞	1.000	9	1.000	0	0
	∞	4	∞	1.000	4	1.000	0	0
neos-5107597-kakapo	1811.40	496089	2144.47	*1.184*	560533	*1.130*	27	1852
	1535.93	414462	1725.41	*1.123*	472393	*1.140*	27	1811
	4448.80	1366902	5927.88	*1.332*	1725439	*1.262*	37	2236
neos-5114902-kasavu	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-5188808-nattai	1269.55	11975	1251.29	0.986	12145	1.014	11	268
	1234.26	12593	1292.07	1.047	13554	*1.076*	8	83
	1631.65	16454	1380.62	**0.846**	12548	**0.763**	10	150
neos-5195221-niemur	3679.70	76893	2813.87	**0.765**	47466	**0.617**	95	3308
	3187.50	31424	2911.85	**0.914**	25010	**0.796**	29	1488
	2916.47	28673	2890.78	0.991	33779	*1.178*	93	4025
neos-631710	14.21%	2	14.21%	1.000	2	1.000	1	0
	8.90%	4	8.90%	1.000	4	1.000	2	1
	14.21%	3	14.21%	1.000	3	1.000	1	0
neos-662469	0.01%	59467	0.01%	1.000	59651	1.003	59	0
	0.04%	59400	0.00%	1.000	50627	0.852	71	1
	0.04%	71726	0.01%	1.000	56995	0.795	51	1
neos-787933	1.37	1	1.37	1.000	1	1.000	3	2
	1.41	1	1.39	0.986	1	1.000	3	2
	1.41	1	1.41	1.000	1	1.000	3	2
neos-827175	6.12	1	6.10	0.997	1	1.000	3	0
	8.31	1	8.21	0.988	1	1.000	4	0
	10.27	1	10.23	0.996	1	1.000	3	0
neos-848589	32.15%	257	32.15%	1.000	256	0.996	5	23
	42.95%	147	42.95%	1.000	148	1.007	5	0
	46.27%	106	46.27%	1.000	106	1.000	4	0
neos-860300	17.33	2	17.27	0.997	2	1.000	3	0
	14.80	3	13.35	**0.902**	2	**0.667**	3	5
	23.07	3	23.18	1.005	3	1.000	6	0
neos-873061	9.28%	158	9.28%	1.000	155	0.981	11	0
	7.72%	148	7.72%	1.000	148	1.000	10	0
	8.12%	168	8.12%	1.000	168	1.000	6	0
neos-911970	0.54%	3799466	1.05%	1.000	1400854	0.369	17	61
	4.07%	2515229	2.49%	1.000	1814127	0.721	20	448
	0.06%	7182902	0.06%	1.000	11460910	1.596	12	35
neos-933966	1374.06	138	1374.28	1.000	138	1.000	17	0
	846.71	38	848.27	1.002	38	1.000	13	0
	2181.81	283	2180.73	1.000	283	1.000	15	5
neos-950242	100.00%	9258	100.00%	1.000	9288	1.003	1	0
	100.00%	8374	100.00%	1.000	8446	1.009	1	0
	100.00%	15629	100.00%	1.000	15629	1.000	1	0
neos-957323	86.33	2	86.06	0.997	2	1.000	7	0
	110.83	5	110.59	0.998	5	1.000	7	2
	79.92	2	80.10	1.002	2	1.000	7	0
neos-960392	882.26	15	881.09	0.999	15	1.000	3	1
	1457.65	102	1439.63	0.988	102	1.000	3	2
	1368.03	438	1363.87	0.997	403	**0.920**	5	1
neos17	26.69	23451	25.95	0.972	22460	0.958	18	69
	9.22	5644	9.39	1.018	5644	1.000	19	55
	9.75	6418	9.84	1.009	6376	0.993	28	213

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
neos5	1164.17	3845856	1007.54	**0.865**	3292114	**0.856**	9	80
	1506.52	5016275	1234.24	**0.819**	4202380	**0.838**	10	181
	1732.23	5988757	1183.51	**0.683**	4100005	**0.685**	10	106
neos859080	0.50	792	0.50	1.000	792	1.000	0	0
	0.57	655	0.54	**0.947**	655	1.000	0	0
	0.53	565	0.55	1.038	565	1.000	0	0
neos8	1.98	1	1.95	0.985	1	1.000	5	9
	1.84	1	1.89	1.027	1	1.000	5	10
	1.82	1	1.83	1.005	1	1.000	6	10
net12	1669.10	1277	1842.42	*1.104*	1211	**0.948**	3	15
	1619.21	1816	1631.28	1.007	1816	1.000	2	13
	1598.93	2932	1561.43	0.977	1695	**0.578**	3	9
netdiversion	849.86	43	848.00	0.998	43	1.000	6	0
	2368.28	88	2364.82	0.999	88	1.000	3	0
	1083.46	27	1087.12	1.003	27	1.000	5	0
nexp-150-20-8-5	3581.20	5786	3539.59	0.988	5786	1.000	7	0
	3684.79	7166	3635.13	0.987	7166	1.000	9	0
	0.83%	12958	0.83%	1.000	13054	1.007	9	0
ns1116954	∞	32	∞	1.000	32	1.000	0	0
	∞	57	∞	1.000	57	1.000	0	0
	∞	72	∞	1.000	75	1.042	0	0
ns1208400	415.49	2004	419.49	1.010	2004	1.000	1	0
	685.36	2339	683.06	0.997	2339	1.000	1	1
	1073.71	2315	1074.09	1.000	2315	1.000	1	0
ns1644855	7.37%	36	7.37%	1.000	36	1.000	1	0
	7.37%	79	7.37%	1.000	79	1.000	1	0
	975.51	1	974.47	0.999	1	1.000	2	3
ns1760995	58.41%	1	58.41%	1.000	1	1.000	2	0
	71.46%	1	71.46%	1.000	1	1.000	2	0
	48.93%	1	48.93%	1.000	1	1.000	2	0
ns1830653	268.69	18612	287.45	*1.070*	14558	**0.782**	7	17
	147.82	10024	134.33	**0.909**	7527	**0.751**	8	56
	149.87	9029	148.24	0.989	7267	**0.805**	12	31
ns1952667	∞	52537	∞	1.000	52208	0.994	0	0
	1411.45	9508	1392.38	0.986	9508	1.000	1	0
	967.39	4900	968.90	1.002	4900	1.000	1	0
nu25-pr12	5.37	53	5.36	0.998	53	1.000	8	0
	6.03	66	6.11	1.013	66	1.000	7	0
	6.06	16	6.05	0.998	16	1.000	10	0
nursesched-medium-hint03	1657.78%	1113	1657.78%	1.000	1100	0.988	10	0
	3021.25%	2054	3021.25%	1.000	2050	0.998	4	0
	1075.72%	1164	1077.84%	1.000	1121	0.963	7	0
nursesched-sprint02	141.95	370	142.08	1.001	370	1.000	6	1
	85.43	409	85.18	0.997	409	1.000	7	5
	67.74	222	67.71	1.000	222	1.000	8	11
nw04	37.96	6	37.93	0.999	6	1.000	8	0
	32.44	6	31.39	0.968	5	**0.833**	9	3
	35.14	6	35.16	1.001	6	1.000	7	0
opm2-z10-s4	25.32%	1059	24.70%	1.000	1000	0.944	23	199
	27.05%	652	27.76%	1.000	586	0.899	7	85
	24.75%	1172	26.96%	1.000	1015	0.866	31	294
p200x1188c	3.50	2	3.53	1.009	2	1.000	5	0
	3.97	3	3.96	0.997	3	1.000	5	0
	3.60	2	3.62	1.006	2	1.000	5	0
peg-solitaire-a3	∞	5754	∞	1.000	5752	1.000	0	0
	∞	3573	∞	1.000	3557	0.996	0	0

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
	∞	3962	∞	1.000	3969	1.002	0	0
pg5_34	1342.11	158032	1173.22	**0.874**	148717	**0.941**	10	144
	956.96	135411	1134.07	*1.185*	144543	*1.067*	13	94
	1368.44	164501	1085.15	**0.793**	121673	**0.740**	12	107
pg	85.76	1362	101.85	*1.188*	2687	*1.973*	13	136
	81.84	812	86.23	*1.054*	1372	*1.690*	8	121
	93.53	1122	107.44	*1.149*	2311	*2.060*	11	137
physicianshed3-3	∞	414	∞	1.000	415	1.002	0	0
	∞	313	∞	1.000	313	1.000	0	0
	∞	361	∞	1.000	361	1.000	0	0
physicianshed6-2	124.61	377	124.81	1.002	377	1.000	3	4
	467.18	2804	462.02	0.989	2804	1.000	1	0
	44.63	1	44.74	1.002	1	1.000	1	0
piperout-08	769.39	107	797.03	1.036	130	*1.215*	13	658
	617.54	797	606.54	0.982	552	**0.693**	34	400
	668.62	123	923.85	*1.382*	596	*4.846*	91	4694
piperout-27	141.37	2	140.11	0.991	2	1.000	2	0
	277.50	566	275.91	0.994	566	1.000	4	26
	254.35	125	332.32	*1.307*	72	**0.576**	23	300
pk1	107.76	302166	107.55	0.998	301100	0.996	14	373
	122.66	355700	109.16	**0.890**	317026	**0.891**	14	380
	126.62	358285	112.34	**0.887**	328715	**0.917**	19	659
proteindesign121hz512p9	12.82%	562	9.60%	1.000	591	1.052	12	8
	15.55%	449	7.94%	1.000	440	0.980	7	20
	26.02%	588	26.02%	1.000	593	1.009	4	0
proteindesign122trx11p8	1.95%	3	1.95%	1.000	3	1.000	1	0
	1.91%	8	1.91%	1.000	8	1.000	1	0
	1.93%	17	1.93%	1.000	17	1.000	2	0
qap10	88.17	3	87.99	0.998	3	1.000	3	0
	112.00	5	111.82	0.998	5	1.000	4	0
	197.84	15	197.87	1.000	15	1.000	4	0
radiationm18-12-05	1.88%	517161	12.99%	1.000	479812	0.928	26	927
	5.59%	517931	0.05%	1.000	750150	1.448	24	983
	3.73%	605173	1.89%	1.000	551080	0.911	20	809
radiationm40-10-02	25.78%	124923	67.02%	1.000	53316	0.427	9	37
	38.15%	118074	57.74%	1.000	27109	0.230	17	114
	21.66%	97696	22.69%	1.000	99008	1.013	21	489
rail01	2.74%	205	2.74%	1.000	200	0.976	5	0
	25.21%	182	25.21%	1.000	182	1.000	5	0
	7.32%	183	7.32%	1.000	183	1.000	7	0
rail02	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
rail507	153.87	623	156.67	1.018	623	1.000	6	2
	178.70	807	180.04	1.007	783	0.970	6	9
	189.56	783	193.43	1.020	771	0.985	5	5
ran14x18-disj-8	1607.37	507875	2109.62	*1.312*	656920	*1.293*	17	47
	1299.76	415692	1785.31	*1.374*	564900	*1.359*	16	137
	1706.14	566717	1694.59	0.993	593570	1.047	17	29
rd-rplusc-21	≥ 10000%	497574	≥ 10000%	1.000	484631	0.974	17	29
	≥ ≥ 10000%	586101	≥ ≥ 10000%	1.000	737139	1.258	12	115
	≥ 10000%	842608	≥ 10000%	1.000	763715	0.906	4	44
reblock115	0.08%	1094405	4390.48	**0.610**	704168	**0.643**	56	8
	6529.63	948735	6605.46	1.012	882785	**0.930**	56	47
	6270.39	823230	5894.68	**0.940**	832788	1.012	47	25
rmatr100-p10	169.97	809	166.48	0.979	809	1.000	5	125

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
	163.48	822	162.84	0.996	822	1.000	5	106
	161.37	783	160.62	0.995	827	*1.056*	6	164
rmatr200-p5	22.40%	420	22.40%	1.000	421	1.002	2	0
	19.56%	422	19.56%	1.000	423	1.002	4	114
	21.08%	393	21.08%	1.000	403	1.025	5	98
rocI-4-11	661.34	12554	638.21	0.965	12970	1.033	4	23
	914.24	15146	1001.80	*1.096*	17602	*1.162*	6	32
	482.83	8950	498.07	1.032	9550	*1.067*	3	20
rocII-5-11	108.07%	3433	108.52%	1.000	3399	0.990	7	66
	154.30%	2803	109.87%	1.000	2764	0.986	4	51
	109.83%	2798	109.11%	1.000	2522	0.901	9	21
rococoB10-011000	13.71%	151272	13.71%	1.000	151103	0.999	35	9
	15.03%	166329	15.09%	1.000	143253	0.861	35	12
	12.78%	167142	12.80%	1.000	153839	0.920	23	5
rococoC10-001000	883.92	55404	765.76	**0.866**	53303	0.962	21	1
	1049.18	63513	851.99	**0.812**	63090	0.993	22	4
	1106.25	108129	1626.91	*1.471*	162527	*1.503*	20	1
roi2alpha3n4	1645.16	14967	1424.80	**0.866**	12529	**0.837**	10	27
	2230.29	20396	1940.46	**0.870**	17446	**0.855**	11	26
	1488.02	13303	1486.54	0.999	13303	1.000	7	26
roi5alpha10n8	34.27%	5403	35.37%	1.000	5989	1.108	11	14
	33.16%	6052	40.36%	1.000	6346	1.049	10	14
	32.12%	6941	32.14%	1.000	6789	0.978	5	12
roll3000	35.36	2179	36.86	1.042	1986	**0.911**	9	12
	37.96	1831	38.91	1.025	2149	*1.174*	10	12
	38.62	1824	60.26	*1.560*	3736	*2.048*	15	6
s100	∞	18	5.53%	1.000	20	1.111	3	0
	29.84%	17	29.84%	1.000	17	1.000	2	0
	1.06%	22	1.06%	1.000	22	1.000	3	0
s250r10	0.28%	23002	0.28%	1.000	22897	0.995	6	0
	6224.25	45419	6366.45	1.023	45426	1.000	7	1
	0.23%	31614	0.23%	1.000	31811	1.006	9	0
satellites2-40	∞	19	∞	1.000	19	1.000	1	0
	∞	4	∞	1.000	4	1.000	1	0
	70.59%	33	70.59%	1.000	33	1.000	3	1
satellites2-60-fs	∞	33	∞	1.000	33	1.000	1	0
	∞	105	∞	1.000	137	1.305	4	16
	∞	28	∞	1.000	28	1.000	1	0
savsched1	∞	1	∞	1.000	1	1.000	2	0
	∞	1	∞	1.000	1	1.000	2	0
	∞	1	∞	1.000	1	1.000	2	0
sct2	0.03%	1108320	0.03%	1.000	600226	0.542	14	12
	0.03%	957797	0.05%	1.000	659682	0.689	19	3
	0.03%	1359038	0.03%	1.000	994927	0.732	20	3
seymour1	80.87	1539	90.45	*1.118*	1627	*1.057*	28	418
	65.65	1370	67.90	1.034	1466	*1.070*	37	290
	72.74	1685	72.05	0.991	1822	*1.081*	50	744
seymour	0.70%	229603	0.66%	1.000	242500	1.056	11	18
	0.72%	224343	0.68%	1.000	222209	0.990	14	30
	0.67%	251797	0.74%	1.000	225373	0.895	13	16
sing326	0.15%	11732	0.15%	1.000	11755	1.002	87	0
	0.17%	8343	0.17%	1.000	8196	0.982	138	0
	0.31%	8062	0.32%	1.000	7997	0.992	7	0
sing44	0.45%	5552	0.45%	1.000	5531	0.996	23	0
	0.19%	7382	0.19%	1.000	7349	0.996	30	0
	0.27%	2269	0.27%	1.000	2267	0.999	8	0

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
snp-02-004-104	0.00%	14354	0.00%	1.000	14561	1.014	11	111
	0.00%	13369	0.00%	1.000	18040	1.349	28	532
	0.00%	23506	0.00%	1.000	19680	0.837	10	56
sorrell3	43.81%	41141	43.81%	1.000	41208	1.002	5	0
	35.59%	39485	35.59%	1.000	39514	1.001	7	0
	19.11%	8909	19.11%	1.000	8801	0.988	6	0
sp150x300d	3.99	3472	3.96	0.992	3472	1.000	4	0
	3.15	2569	3.12	0.990	2569	1.000	4	0
	1.34	848	1.29	0.963	848	1.000	4	0
sp97ar	1.11%	22615	0.98%	1.000	15747	0.696	21	4
	0.69%	27883	1.02%	1.000	22961	0.823	33	4
	1.02%	24604	1.53%	1.000	24828	1.009	25	4
sp98ar	0.83%	43658	1.43%	1.000	71746	1.643	26	3
	0.87%	43138	0.48%	1.000	67060	1.555	21	7
	1.21%	66073	0.98%	1.000	71271	1.079	27	5
splice1k1	304.58%	1099	309.20%	1.000	513	0.467	5	22
	306.97%	648	376.10%	1.000	594	0.917	6	34
	4746.83	532	358.74%	1.517	834	1.568	4	6
square41	109.98%	30	109.98%	1.000	30	1.000	5	4
	89.32%	38	89.32%	1.000	37	0.974	4	4
	92.32%	27	92.32%	1.000	28	1.037	5	6
square47	231.21%	4	231.21%	1.000	4	1.000	3	2
	117.00%	13	117.00%	1.000	13	1.000	4	4
	231.21%	1	231.21%	1.000	1	1.000	3	2
supportcase10	803.51%	1	803.51%	1.000	1	1.000	2	0
	989.07%	1	989.07%	1.000	1	1.000	2	0
	1054.36%	1	1054.36%	1.000	1	1.000	2	0
supportcase12	1.31%	1486	1.31%	1.000	1463	0.985	5	168
	1.11%	2031	1.35%	1.000	2297	1.131	3	15
	1.30%	1408	1.30%	1.000	1505	1.069	3	73
supportcase18	3.84%	431569	3.84%	1.000	419350	0.972	5	7
	5.96%	190081	5.96%	1.000	237591	1.250	4	2
	3.84%	198696	3.84%	1.000	198815	1.001	6	5
supportcase19	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
supportcase22	∞	51	∞	1.000	51	1.000	0	0
	∞	18	∞	1.000	18	1.000	0	0
	∞	66	∞	1.000	66	1.000	0	0
supportcase26	10.01%	7955502	8.94%	1.000	8135621	1.023	20	642
	3371.98	4347822	5238.22	*1.553*	6761735	*1.555*	13	590
	5922.38	7264783	4487.28	**0.758**	5497025	**0.757**	21	618
supportcase33	1568.43	13263	1598.38	1.019	12756	0.962	9	1
	1615.24	7176	1600.98	0.991	7176	1.000	6	0
	680.69	3786	682.16	1.002	3786	1.000	10	0
supportcase40	782.31	6335	786.50	1.005	6335	1.000	20	355
	946.22	7931	946.94	1.001	7991	1.008	24	517
	801.52	6970	797.74	0.995	6970	1.000	24	507
supportcase42	0.12%	405169	0.38%	1.000	305571	0.754	57	2576
	0.12%	467910	0.10%	1.000	380155	0.812	34	1232
	0.24%	345585	0.35%	1.000	467610	1.353	19	794
supportcase6	9.13%	19336	9.13%	1.000	18980	0.982	14	1
	8.92%	13800	8.41%	1.000	17726	1.284	11	8
	9.74%	17532	9.72%	1.000	17709	1.010	12	1
supportcase7	180.95	59	179.98	0.995	59	1.000	7	76
	193.47	47	193.62	1.001	45	0.957	4	30

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Table A.4: Detailed computational results on MIPLIB 2017 benchmark with and without updating dual boundexceeding proofs.

	update disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	I	Upd
	210.50	32	210.25	0.999	32	1.000	4	80
swath1	21.15	285	21.09	0.997	281	0.986	9	22
	17.95	257	17.34	0.966	245	0.953	4	3
	18.29	260	19.82	*1.084*	292	*1.123*	6	13
swath3	243.56	31878	226.20	**0.929**	28316	**0.888**	13	6
	183.58	21504	182.91	0.996	21837	1.015	8	3
	421.75	74953	427.45	1.014	74192	0.990	7	7
tbfp-network	2356.43	574	2356.81	1.000	574	1.000	11	0
	1681.30	71	1683.80	1.001	71	1.000	3	0
	1089.98	99	1088.57	0.999	99	1.000	5	0
thor50dday	23.30%	95	23.30%	1.000	95	1.000	9	0
	21.49%	12	21.49%	1.000	12	1.000	12	0
	14.80%	33	14.80%	1.000	34	1.030	9	0
timtab1	73.25	60661	73.73	1.007	64175	*1.058*	72	36
	65.75	49252	67.90	1.033	51540	1.046	68	164
	70.44	54418	70.92	1.007	55054	1.012	52	93
tr12-30	720.20	499607	606.97	**0.843**	423661	**0.848**	20	841
	657.58	486251	650.32	0.989	475420	0.978	18	655
	403.35	215444	397.52	0.986	213946	0.993	16	373
traininstance2	∞	66630	∞	1.000	67099	1.007	15	17
	∞	44225	∞	1.000	52063	1.177	5	15
	∞	73356	6286.13%	1.000	73138	0.997	10	9
traininstance6	609.06%	548117	634.16%	1.000	456248	0.832	18	122
	229.50%	453251	626.92%	1.000	347529	0.767	39	180
	673.91%	395633	520.12%	1.000	454368	1.148	26	295
trento1	0.08%	55337	0.07%	1.000	57766	1.044	42	4
	0.06%	73064	0.10%	1.000	51033	0.698	36	2
	3.98%	36871	1.67%	1.000	35013	0.950	35	2
triptim1	1109.49	8	1099.43	0.991	8	1.000	6	0
	752.71	7	747.73	0.993	7	1.000	3	0
	1066.26	8	1065.09	0.999	8	1.000	4	0
uccase12	0.00%	76857	0.00%	1.000	77800	1.012	11	66
	0.00%	84315	0.00%	1.000	91468	1.085	12	99
	0.00%	89984	0.00%	1.000	98605	1.096	12	97
uccase9	1.98%	545	1.98%	1.000	498	0.914	8	20
	2.73%	702	1.48%	1.000	1166	1.661	8	29
	1.40%	614	2.82%	1.000	550	0.896	7	4
uct-subprob	1114.97	44339	1102.62	0.989	44339	1.000	19	2
	1813.07	65873	1631.60	**0.900**	59559	**0.904**	21	1
	2485.14	94985	2506.36	1.009	95674	1.007	21	3
unitcal_7	273.78	89	272.59	0.996	89	1.000	2	0
	296.89	176	298.12	1.004	180	1.023	3	75
	386.01	436	387.18	1.003	436	1.000	2	0
var-smallemery-m6j6	1.07%	568063	0.93%	1.000	568323	1.000	6	33
	0.86%	671886	0.87%	1.000	656232	0.977	4	14
	6115.89	669677	6729.45	*1.100*	683202	1.020	4	17
wachplan	2340.02	219938	2340.84	1.000	219938	1.000	1	0
	3427.00	302179	3419.67	0.998	302179	1.000	1	0
	2343.20	198054	2343.95	1.000	198054	1.000	1	0

Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
30n20b8	149.79	171	149.68	0.999	171	1.000	14	1.27
	621.66	1999	623.60	1.003	1999	1.000	285	0.84
	688.46	3499	693.56	1.007	3499	1.000	510	0.82
50v-10	2.18%	747722	1.69%	1.000	829421	1.109	7156	0.43
	1.36%	1062430	1.15%	1.000	867997	0.817	3951	0.46
	1.14%	826465	1.37%	1.000	833134	1.008	2537	0.52
CMS750_4	185.34	2028	185.73	1.002	2028	1.000	0	–
	371.03	3254	370.72	0.999	3254	1.000	0	–
	472.14	13518	473.12	1.002	13518	1.000	0	–
academictimetablesmall	∞	2317	∞	1.000	2315	0.999	0	–
	∞	3503	∞	1.000	3505	1.001	0	–
	∞	2673	∞	1.000	2681	1.003	0	–
air05	40.21	648	40.07	0.997	648	1.000	0	–
	36.72	716	36.54	0.995	716	1.000	0	–
	30.45	282	30.22	0.992	282	1.000	0	–
app1-1	3.50	2	3.53	1.009	2	1.000	0	–
	4.93	3	4.94	1.002	3	1.000	0	–
	4.16	6	4.17	1.002	6	1.000	0	–
app1-2	644.43	33	642.80	0.997	33	1.000	0	–
	791.01	20	789.47	0.998	20	1.000	0	–
	619.82	20	618.36	0.998	20	1.000	0	–
assign1-5-8	4.74%	5735311	4.74%	1.000	5736357	1.000	1723	1.50
	4.54%	6824672	4.54%	1.000	6813236	0.998	1766	1.51
	4.80%	6338756	4.80%	1.000	6333262	0.999	2108	1.52
atlanta-ip	3.64%	18389	3.60%	1.000	18533	1.008	125	0.56
	3.75%	22064	3.81%	1.000	21153	0.959	252	0.74
	4.26%	31162	4.27%	1.000	30903	0.992	130	0.66
b1c1s1	17.12%	36011	17.13%	1.000	35962	0.999	39	0.52
	18.37%	21102	18.36%	1.000	21112	1.000	28	0.52
	17.69%	18661	17.69%	1.000	18673	1.001	37	0.47
bab2	1.29%	3493	1.29%	1.000	3473	0.994	0	–
	1.10%	3384	2.44%	1.000	3262	0.964	0	–
	∞	1980	∞	1.000	1981	1.001	0	–
bab6	0.58%	4926	0.58%	1.000	4790	0.972	0	–
	1.14%	3242	1.14%	1.000	3258	1.005	0	–
	1.94%	4745	1.94%	1.000	4779	1.007	0	–
beasleyC3	31.55	83	31.56	1.000	83	1.000	0	–
	17.35	2	17.35	1.000	2	1.000	0	–
	47.00	453	47.20	1.004	453	1.000	6	1.18
binkar10_1	30.74	2538	31.34	1.020	2560	1.009	407	0.11
	29.10	2233	29.22	1.004	2246	1.006	323	0.13
	28.98	2529	28.71	0.991	2509	0.992	407	0.12
blp-ar98	0.27%	237752	0.27%	1.000	238231	1.002	0	–
	0.33%	208073	0.33%	1.000	207500	0.997	0	–
	0.32%	228758	0.32%	1.000	229423	1.003	0	–
blp-ic98	1.38%	309577	1.38%	1.000	304769	0.984	0	–
	2.41%	255635	2.41%	1.000	254061	0.994	0	–
	2.11%	281142	2.11%	1.000	278188	0.989	0	–
bnatt400	972.47	6821	970.91	0.998	6821	1.000	0	–
	1101.70	6346	1105.02	1.003	6346	1.000	0	–
	743.69	5500	745.15	1.002	5500	1.000	0	–
bnatt500	4372.13	29526	4368.17	0.999	29526	1.000	0	–
	6325.95	38962	6333.06	1.001	38962	1.000	0	–
	4992.95	29029	4996.90	1.001	29029	1.000	0	–
bppc4-08	1.92%	800013	1.92%	1.000	797503	0.997	0	–

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
	1.92%	886475	1.92%	1.000	938927	1.059	3	0.71
	1.92%	817145	1.92%	1.000	793397	0.971	10	0.38
brazil3	3363.06	2570	3360.46	0.999	2570	1.000	121	0.78
	4255.44	2347	4252.19	0.999	2347	1.000	19	0.75
	3795.74	3302	3785.08	0.997	3302	1.000	1	1.07
buildingenergy	0.13%	95	0.13%	1.000	96	1.011	95	0.00
	0.15%	85	0.15%	1.000	85	1.000	234	0.00
	0.13%	12	0.13%	1.000	12	1.000	0	–
cbs-cta	40.13	1	40.27	1.003	1	1.000	0	–
	314.48	31	314.10	0.999	31	1.000	0	–
	35.73	1	35.77	1.001	1	1.000	0	–
chromaticindex1024-7	33.33%	968	33.33%	1.000	964	0.996	0	–
	33.33%	1155	33.33%	1.000	1171	1.014	0	–
	6425.84	757	6429.72	1.001	757	1.000	0	–
chromaticindex512-7	1185.02	361	1172.37	0.989	361	1.000	0	–
	3707.63	3133	3689.97	0.995	3133	1.000	0	–
	33.33%	40832	33.33%	1.000	40579	0.994	0	–
cmflsp50-24-8-8	3.98%	35760	3.98%	1.000	36090	1.009	1326	0.21
	2.09%	81376	1.99%	1.000	85475	1.050	2330	0.14
	3.80%	35336	4.86%	1.000	37790	1.069	456	0.19
co-100	1.74%	54003	1.74%	1.000	54008	1.000	0	–
	91.77%	7012	91.77%	1.000	7012	1.000	0	–
	3.05%	10693	3.18%	1.000	10565	0.988	0	–
cod105	47.41%	7347	47.57%	1.000	7261	0.988	0	–
	48.00%	6829	48.00%	1.000	6829	1.000	0	–
	48.06%	6621	48.07%	1.000	6601	0.997	0	–
comp07-2idx	966.67%	3999	966.67%	1.000	3996	0.999	22	0.51
	2800.00%	745	2800.00%	1.000	743	0.997	12	0.43
	1716.67%	1454	1716.67%	1.000	1449	0.997	15	0.44
comp21-2idx	247.43%	10854	247.43%	1.000	10931	1.007	15	0.50
	195.50%	9837	195.50%	1.000	9835	1.000	473	0.52
	248.72%	11693	248.72%	1.000	11711	1.002	20	0.51
cost266-UUE	5039.76	383777	4923.15	0.977	375684	0.979	35	0.05
	3690.46	294630	3728.83	1.010	294630	1.000	37	0.07
	4047.47	306702	4067.72	1.005	306702	1.000	17	0.07
cryptanalysiskb128n5obj14	∞	110	∞	1.000	110	1.000	0	–
	∞	55	∞	1.000	59	1.073	0	–
	∞	90	∞	1.000	90	1.000	0	–
cryptanalysiskb128n5obj16	∞	105	∞	1.000	104	0.990	0	–
	2799.12	37	2790.65	0.997	37	1.000	0	–
	∞	96	∞	1.000	97	1.010	0	–
csched007	3089.69	186152	2327.77	**0.753**	187288	1.006	167	1.07
	3376.84	272891	2613.95	**0.774**	220934	**0.810**	236	1.05
	2753.44	225167	3393.08	*1.232*	247755	*1.100*	205	1.12
csched008	1.16%	528705	2.81%	1.000	455870	0.862	39830	1.08
	3986.19	370049	2.33%	1.806	694455	1.877	95479	1.07
	6352.31	516838	5772.95	**0.909**	546382	*1.057*	96670	1.05
cvs16r128-89	23.28%	67993	23.28%	1.000	67980	1.000	0	–
	22.61%	34961	22.61%	1.000	34973	1.000	0	–
	23.00%	47542	23.01%	1.000	47219	0.993	0	–
dano3_3	144.01	10	143.70	0.998	10	1.000	0	–
	142.48	14	142.65	1.001	14	1.000	0	–
	124.93	17	124.56	0.997	17	1.000	0	–
dano3_5	635.51	276	635.04	0.999	276	1.000	46	0.01
	285.29	159	285.81	1.002	159	1.000	23	0.01
	286.06	140	285.94	1.000	140	1.000	15	0.01

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
decomp2	2.42	1	2.39	0.988	1	1.000	0	–
	2.47	1	2.42	0.980	1	1.000	0	–
	2.43	1	2.50	1.029	1	1.000	0	–
drayage-100-23	16.49	32	16.43	0.996	32	1.000	0	–
	19.62	48	19.52	0.995	48	1.000	0	–
	13.51	16	13.50	0.999	16	1.000	0	–
drayage-25-23	0.07%	722507	0.07%	1.000	720814	0.998	0	–
	0.07%	798785	0.07%	1.000	790871	0.990	0	–
	6880.95	552534	6941.84	1.009	552534	1.000	0	–
dws008-01	46.68%	137095	44.84%	1.000	144766	1.056	36767	0.18
	48.40%	176861	44.28%	1.000	157395	0.890	35465	0.20
	47.52%	167529	52.63%	1.000	153108	0.914	33665	0.21
eil33-2	78.12	343	81.20	1.039	343	1.000	0	–
	101.86	395	101.92	1.001	395	1.000	0	–
	103.61	541	105.72	1.020	541	1.000	0	–
eilA101-2	20.05%	11042	20.05%	1.000	11110	1.006	0	–
	13.19%	12903	13.20%	1.000	12688	0.983	0	–
	13.37%	14025	13.37%	1.000	13480	0.961	0	–
enlight_hard	0.50	1	0.50	1.000	1	1.000	0	–
	0.50	1	0.50	1.000	1	1.000	0	–
	0.50	1	0.50	1.000	1	1.000	0	–
ex10	494.11	1	493.80	0.999	1	1.000	0	–
	501.07	1	497.94	0.994	1	1.000	0	–
	577.37	1	581.12	1.006	1	1.000	0	–
ex9	27.83	1	27.98	1.005	1	1.000	0	–
	27.26	1	27.30	1.001	1	1.000	0	–
	27.82	1	27.02	0.971	1	1.000	0	–
exp-1-500-5-5	2.27	1	2.28	1.004	1	1.000	0	–
	2.21	1	2.22	1.005	1	1.000	0	–
	2.24	1	2.21	0.987	1	1.000	0	–
fast0507	318.59	1284	322.23	1.011	1284	1.000	0	–
	276.89	1223	280.17	1.012	1223	1.000	0	–
	360.83	1711	365.44	1.013	1711	1.000	0	–
fastxgemm-n2r6s0t2	4242.55	988905	4702.82	*1.108*	1118937	*1.131*	28031	0.59
	2081.00	481982	4017.11	*1.930*	1012967	*2.102*	21034	0.56
	3463.31	800783	3129.08	**0.903**	769500	0.961	14363	0.56
fhnw-binpack4-48	∞	4061123	∞	1.000	4040499	0.995	0	–
	∞	3518315	∞	1.000	3525851	1.002	0	–
	∞	3409002	∞	1.000	3413924	1.001	0	–
fhnw-binpack4-4	∞	15353678	∞	1.000	14733968	0.960	81	1.09
	∞	13725022	∞	1.000	13981261	1.019	205	1.21
	∞	11634465	∞	1.000	11607995	0.998	84	1.27
fiball	467.24	4111	465.55	0.996	4111	1.000	18	0.47
	449.57	3521	447.14	0.995	3521	1.000	8	17.21
	500.19	5672	499.03	0.998	5672	1.000	17	37.59
gen-ip002	1418.20	6087223	1315.68	**0.928**	5856334	0.962	5748	0.47
	1287.18	5462632	1295.56	1.007	5478569	1.003	5224	0.47
	1263.62	5583755	1271.92	1.007	5583912	1.000	5725	0.47
gen-ip054	3377.24	17017459	3047.64	**0.902**	15245360	**0.896**	31206	0.51
	2379.40	11995879	2530.93	*1.064*	12476019	1.040	28121	0.51
	3269.89	16034948	3381.24	1.034	16438070	1.025	38360	0.50
germanrr	1.46%	3402	1.46%	1.000	3418	1.005	7	1.43
	2.11%	2854	2.11%	1.000	2851	0.999	6	1.42
	1.94%	3562	1.94%	1.000	3559	0.999	9	1.44
gfd-schedulen180f7d50m30k18	∞	4	∞	1.000	4	1.000	0	–
	∞	8	∞	1.000	8	1.000	0	–

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
	∞	10	∞	1.000	10	1.000	0	–
glass-sc	2682.48	241329	2655.26	0.990	241329	1.000	0	–
	3214.72	289206	3214.67	1.000	289206	1.000	0	–
	2814.93	251112	2819.06	1.001	251112	1.000	0	–
glass4	4034.07	3057251	4008.75	0.994	2705421	**0.885**	2044	0.64
	1869.97	1494449	2392.84	*1.280*	1888717	*1.264*	1172	0.62
	2101.40	1854280	2212.84	*1.053*	1599046	**0.862**	476	0.66
gmu-35-40	0.05%	2049300	0.05%	1.000	2051936	1.001	33	0.84
	0.03%	2081244	0.03%	1.000	2099939	1.009	64	0.83
	0.03%	1310351	0.03%	1.000	1381092	1.054	49	0.83
gmu-35-50	0.02%	1327256	0.02%	1.000	1317781	0.993	52	0.75
	0.03%	1247462	0.03%	1.000	1247342	1.000	12	0.74
	0.04%	1018626	0.04%	1.000	1016723	0.998	5	0.82
graph20-20-1rand	163.83%	6111	163.73%	1.000	6171	1.010	0	–
	165.38%	8260	165.38%	1.000	8277	1.002	0	–
	172.66%	7489	172.66%	1.000	7513	1.003	0	–
graphdraw-domain	1014.34	1788814	1010.47	0.996	1823083	1.019	1033	0.86
	1180.52	1989742	1122.85	0.951	1941578	0.976	1117	0.89
	1675.10	2907888	1664.67	0.994	2907888	1.000	956	0.91
h80x6320d	69.46	4	69.54	1.001	4	1.000	0	–
	86.02	10	86.17	1.002	10	1.000	2	1.74
	85.29	5	86.62	1.016	5	1.000	2	1.52
highschool1-aigio	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
hypothyroid-k1	19.94	1	20.04	1.005	1	1.000	0	–
	19.86	1	19.99	1.007	1	1.000	0	–
	19.91	1	20.16	1.013	1	1.000	0	–
ic97_potential	0.78%	7119448	0.84%	1.000	7214792	1.013	48200	1.08
	0.63%	6496840	0.75%	1.000	6107856	0.940	54828	1.11
	0.81%	7458325	0.86%	1.000	7579116	1.016	41892	1.07
icir97_tension	0.09%	3094293	0.07%	1.000	3185773	1.030	30127	0.15
	5939.53	2269531	0.05%	1.212	2776552	1.223	47607	0.14
	0.11%	3113728	0.08%	1.000	2729235	0.877	28506	0.12
irish-electricity	∞	93	∞	1.000	93	1.000	0	–
	26.60%	1359	18.43%	1.000	1317	0.969	71	0.10
	∞	1333	∞	1.000	1333	1.000	337	0.37
irp	12.53	6	12.51	0.998	6	1.000	0	–
	12.07	4	12.05	0.998	4	1.000	0	–
	12.62	5	12.58	0.997	5	1.000	0	–
istanbul-no-cutoff	154.51	347	154.02	0.997	347	1.000	0	–
	166.45	245	166.34	0.999	245	1.000	0	–
	286.40	475	285.14	0.996	475	1.000	6	0.41
k1mushroom	1889.56	7	1897.56	1.004	7	1.000	0	–
	1594.37	11	1583.93	0.993	11	1.000	0	–
	1318.45	3	1321.29	1.002	3	1.000	0	–
lectsched-5-obj	153.33%	173223	166.67%	1.000	148725	0.859	1718	0.88
	106.67%	129184	120.00%	1.000	130812	1.013	1006	0.50
	133.33%	63608	126.67%	1.000	64923	1.021	587	0.81
leo1	6.11%	80654	6.11%	1.000	80819	1.002	0	–
	7.14%	34868	7.14%	1.000	34905	1.001	0	–
	7.53%	45878	7.53%	1.000	45969	1.002	0	–
leo2	∞	101695	∞	1.000	101616	0.999	0	–
	∞	110297	∞	1.000	110967	1.006	0	–
	∞	146844	∞	1.000	146706	0.999	0	–
lotsize	0.67%	16481	0.67%	1.000	16786	1.019	4	0.82

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
	0.88%	20469	0.88%	1.000	20493	1.001	2	1.40
	0.70%	18014	0.70%	1.000	17911	0.994	2	0.93
mad	∞	13194508	∞	1.000	8295624	0.629	36	0.67
	∞	13913907	∞	1.000	14934806	1.073	145	0.59
	∞	16445546	∞	1.000	15381075	0.935	44	0.68
map10	1001.07	1640	1006.71	1.006	1637	0.998	112	0.74
	630.31	724	633.84	1.006	724	1.000	117	0.75
	805.35	979	792.96	0.985	965	0.986	113	0.75
map16715-04	2157.11	1933	2158.43	1.001	1933	1.000	63	0.96
	2330.54	2173	2335.51	1.002	2173	1.000	62	0.96
	2123.63	1977	2160.04	1.017	1990	1.007	70	0.96
markshare2	∞	5824114	∞	1.000	5827069	1.001	0	–
	∞	5581007	∞	1.000	5581862	1.000	0	–
	∞	5023615	∞	1.000	5052479	1.006	0	–
markshare_4_0	73.16	612396	72.47	0.991	612396	1.000	0	–
	70.50	589762	70.48	1.000	589762	1.000	0	–
	86.61	719508	85.88	0.992	719508	1.000	0	–
mas74	1678.96	4932223	1680.79	1.001	4932223	1.000	5015	1.08
	2275.04	7992914	2282.09	1.003	7992914	1.000	11712	1.09
	1569.06	4674399	1563.59	0.997	4674399	1.000	5842	1.09
mas76	135.44	406104	136.88	1.011	406104	1.000	702	1.12
	167.03	525538	168.46	1.009	525538	1.000	765	1.13
	148.41	450422	152.65	1.029	450422	1.000	736	1.13
mc11	147.87	6484	149.40	1.010	6484	1.000	29	1.85
	80.00	1411	80.39	1.005	1411	1.000	6	2.00
	104.92	3386	106.11	1.011	3386	1.000	21	1.85
mcsched	317.74	11378	318.21	1.001	11378	1.000	0	–
	235.29	9846	235.33	1.000	9846	1.000	0	–
	306.34	12017	306.32	1.000	12017	1.000	0	–
mik-250-20-75-4	52.68	23893	52.78	1.002	23893	1.000	167	0.32
	43.90	15175	43.96	1.001	15175	1.000	212	0.32
	52.15	20733	52.36	1.004	20733	1.000	213	0.29
milo-v12-6-r2-40-1	10.82%	260926	9.47%	1.000	189681	0.727	13811	0.84
	11.22%	297446	8.96%	1.000	323326	1.087	24417	0.83
	10.31%	224778	11.33%	1.000	417232	1.856	30891	0.76
momentum1	8.61%	101918	24.76%	1.000	94037	0.923	6578	0.15
	6.30%	124819	7.36%	1.000	91471	0.733	8924	0.16
	6.17%	196712	6.53%	1.000	188055	0.956	10931	0.15
mushroom-best	575.72	26972	579.50	1.007	27393	1.016	1310	0.65
	134.00%	94997	134.09%	1.000	94624	0.996	1580	0.85
	100.03%	82549	121.97%	1.000	98893	1.198	2824	0.88
mzzv11	210.46	484	210.71	1.001	484	1.000	2	0.87
	263.22	987	263.08	0.999	987	1.000	4	0.78
	195.36	616	195.89	1.003	616	1.000	0	–
mzzv42z	175.15	415	175.26	1.001	415	1.000	1	0.95
	244.76	712	246.00	1.005	712	1.000	6	0.94
	308.91	719	306.34	0.992	719	1.000	4	0.87
n2seq36q	925.30	5438	936.81	1.012	5438	1.000	0	–
	1064.07	4712	1061.28	0.997	4712	1.000	0	–
	1167.24	4632	1170.79	1.003	4632	1.000	0	–
n3div36	2.56%	225155	2.59%	1.000	213866	0.950	0	–
	2.84%	212152	2.86%	1.000	207136	0.976	0	–
	2.67%	212483	2.69%	1.000	202891	0.955	0	–
n5-3	26.47	926	26.40	0.997	926	1.000	3	0.17
	27.69	971	27.79	1.004	971	1.000	2	0.09
	27.24	1087	27.09	0.994	1087	1.000	0	–

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
neos-1122047	9.69	1	9.92	1.024	1	1.000	0	–
	9.66	1	9.76	1.010	1	1.000	0	–
	9.82	1	9.70	0.988	1	1.000	0	–
neos-1171448	7.19	1	58.11	*8.082*	101	*101.000*	1	1.00
	4163.96	322	5.16	**0.001**	1	**0.003**	1	1.00
	51.15	86	51.55	1.008	86	1.000	1	1.00
neos-1171737	1.04%	3921	1.04%	1.000	3912	0.998	29	0.54
	1.30%	3941	1.56%	1.000	4009	1.017	16	0.52
	1.21%	17078	1.30%	1.000	11719	0.686	199	0.56
neos-1354092	∞	613	∞	1.000	613	1.000	3	1.00
	∞	830	∞	1.000	820	0.988	1	0.50
	∞	639	∞	1.000	639	1.000	3	0.83
neos-1445765	43.81	133	43.72	0.998	133	1.000	0	–
	44.21	141	44.19	1.000	141	1.000	0	–
	44.68	125	44.74	1.001	125	1.000	0	–
neos-1456979	7.49%	39921	7.49%	1.000	39961	1.001	0	–
	6.84%	38705	6.84%	1.000	38750	1.001	1	0.34
	7.31%	31441	7.29%	1.000	31540	1.003	0	–
neos-1582420	21.72	18	21.85	1.006	18	1.000	53	1.31
	10.82	9	10.92	1.009	9	1.000	18	0.67
	54.77	1381	55.49	1.013	1381	1.000	323	0.56
neos-2075418-temuka	6956.95	1	7024.05	1.010	1	1.000	0	–
	4539.56	1	4517.94	0.995	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
neos-2657525-crna	∞	1566240	∞	1.000	3064132	1.956	193448	1.13
	∞	3679874	∞	1.000	3681104	1.000	172895	1.15
	∞	2117578	∞	1.000	2122332	1.002	102544	1.11
neos-2746589-doon	0.46%	57311	0.46%	1.000	55681	0.972	1	0.65
	0.73%	31231	0.73%	1.000	30280	0.970	0	–
	0.11%	187900	0.11%	1.000	182349	0.970	3	0.82
neos-2978193-inde	0.50%	564299	0.50%	1.000	549249	0.973	3126	0.01
	0.13%	597757	0.13%	1.000	573707	0.960	2312	0.01
	0.50%	566106	0.50%	1.000	548119	0.968	3982	0.01
neos-2987310-joes	17.66	1	17.49	0.990	1	1.000	0	–
	15.44	1	15.31	0.992	1	1.000	0	–
	13.71	1	13.67	0.997	1	1.000	0	–
neos-3004026-krka	53.25	2711	53.06	0.996	2711	1.000	0	–
	62.55	3485	62.47	0.999	3485	1.000	0	–
	46.71	1764	46.28	0.991	1764	1.000	0	–
neos-3024952-loue	4367.65	401234	4646.86	*1.064*	383076	0.955	6231	7.28
	0.07%	703845	0.07%	1.000	688312	0.978	24515	7.14
	0.06%	877914	0.04%	1.000	1114650	1.270	14504	7.07
neos-3046615-murg	167.80%	7177613	169.81%	1.000	6971706	0.971	1756	0.95
	166.97%	6299859	166.11%	1.000	6364063	1.010	1967	0.96
	165.78%	6632917	163.66%	1.000	7613539	1.148	2441	0.96
neos-3083819-nubu	12.03	2020	12.72	*1.057*	2020	1.000	172	1.02
	11.24	1578	12.37	*1.101*	1578	1.000	398	1.03
	18.90	3812	20.79	*1.100*	3812	1.000	471	1.01
neos-3216931-puriri	167.08%	7443	116.41%	1.000	5546	0.745	191	0.75
	48.17%	10428	5.50%	1.000	9705	0.931	294	0.78
	145.61%	4910	147.13%	1.000	4790	0.976	112	0.76
neos-3381206-awhea	1.20	1	1.18	0.983	1	1.000	0	–
	1.23	1	1.21	0.984	1	1.000	0	–
	1.21	1	1.20	0.992	1	1.000	0	–
neos-3402294-bobin	4388.20	40294	4386.37	1.000	40294	1.000	0	–
	623.92	3428	618.95	0.992	3428	1.000	0	–

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
	1624.98	9242	1620.92	0.998	9242	1.000	0	–
neos-3402454-bohle	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
neos-3555904-turama	18.01%	145	18.01%	1.000	145	1.000	0	–
	∞	18	∞	1.000	18	1.000	0	–
	18.01%	16864	18.01%	1.000	16797	0.996	0	–
neos-3627168-kasai	0.17%	4712130	0.15%	1.000	4555684	0.967	4738	1.17
	0.09%	4139311	0.09%	1.000	4132791	0.998	3038	1.09
	0.27%	5183140	0.27%	1.000	5147129	0.993	3765	1.15
neos-3656078-kumeu	∞	32	∞	1.000	32	1.000	0	–
	∞	79	∞	1.000	82	1.038	2	0.08
	∞	122	∞	1.000	122	1.000	1	0.67
neos-3754480-nidda	∞	19975340	∞	1.000	20000763	1.001	1097	0.29
	∞	18490973	∞	1.000	18439214	0.997	1076	0.30
	∞	19202321	∞	1.000	19108471	0.995	384	0.32
neos-3988577-wolgan	∞	309	∞	1.000	312	1.010	0	–
	∞	180	∞	1.000	179	0.994	0	–
	∞	439	∞	1.000	439	1.000	0	–
neos-4300652-rahue	438.74%	1353	431.97%	1.000	1365	1.009	165	0.08
	809.48%	1234	809.48%	1.000	1213	0.983	178	0.13
	316.83%	2125	316.83%	1.000	2127	1.001	146	0.22
neos-4338804-snowy	1.37%	5465626	1.66%	1.000	4875741	0.892	23455	0.85
	0.82%	7085230	0.82%	1.000	6738902	0.951	29841	0.81
	2.07%	6055267	1.66%	1.000	5067404	0.837	19238	0.94
neos-4387871-tavua	11.38%	120515	11.39%	1.000	118375	0.982	3047	0.31
	13.13%	120082	14.13%	1.000	116171	0.967	3835	0.28
	13.51%	96819	18.66%	1.000	96695	0.999	2449	0.35
neos-4413714-turia	303.39	2	299.23	0.986	2	1.000	0	–
	416.44	2	404.80	0.972	2	1.000	0	–
	282.20	2	277.10	0.982	2	1.000	0	–
neos-4532248-waihi	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
neos-4647030-tutaki	0.01%	24465	0.01%	1.000	24413	0.998	15	0.97
	0.01%	22665	0.01%	1.000	22893	1.010	15	0.97
	0.01%	27208	0.01%	1.000	27292	1.003	5	0.78
neos-4722843-widden	2638.33	11357	2651.33	1.005	11357	1.000	9	0.04
	1020.20	3376	1033.65	1.013	3376	1.000	41	0.37
	1707.37	7919	1714.52	1.004	7919	1.000	28	0.18
neos-4738912-atrato	702.38	60433	813.40	*1.158*	61981	1.026	16069	0.41
	3660.73	324992	3808.90	1.040	324992	1.000	43651	0.39
	867.84	95736	914.39	*1.054*	95736	1.000	16467	0.82
neos-4763324-toguru	46.04%	8436	46.04%	1.000	8436	1.000	0	–
	45.06%	15192	45.08%	1.000	14962	0.985	0	–
	48.94%	7145	48.94%	1.000	7145	1.000	0	–
neos-4954672-berkel	8.46%	956670	8.48%	1.000	1019990	1.066	3126	0.53
	8.88%	783295	8.71%	1.000	819107	1.046	2272	0.50
	8.73%	837840	8.00%	1.000	891993	1.065	2753	0.49
neos-5049753-cuanza	∞	52	∞	1.000	52	1.000	0	–
	15.39%	14	15.39%	1.000	14	1.000	0	–
	15.20%	12	15.20%	1.000	12	1.000	0	–
neos-5052403-cygnet	1.60%	113	1.60%	1.000	113	1.000	0	–
	1.38%	1	1.38%	1.000	1	1.000	0	–
	1.19%	63	1.19%	1.000	63	1.000	0	–
neos-5093327-huahum	10.30%	50228	10.32%	1.000	49854	0.993	1	0.05

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
	10.43%	52521	10.43%	1.000	52521	1.000	3	0.04
	12.13%	49012	12.17%	1.000	48532	0.990	1	0.05
neos-5104907-jarama	∞	8	∞	1.000	8	1.000	0	–
	∞	9	∞	1.000	9	1.000	0	–
	∞	4	∞	1.000	4	1.000	0	–
neos-5107597-kakapo	2672.94	882141	2144.47	**0.802**	560533	**0.635**	46	0.67
	1724.83	472393	1725.41	1.000	472393	1.000	9	0.66
	3597.91	1115823	5927.88	*1.648*	1725439	*1.546*	112	0.80
neos-5114902-kasavu	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
neos-5188808-nattai	1283.68	12101	1251.29	0.975	12145	1.004	251	0.16
	1300.65	13483	1292.07	0.993	13554	1.005	355	0.18
	1336.30	12479	1380.62	1.033	12548	1.006	396	0.17
neos-5195221-niemur	3115.64	62799	2813.87	**0.903**	47466	**0.756**	11	0.27
	2897.10	25010	2911.85	1.005	25010	1.000	3	0.18
	2854.80	45135	2890.78	1.013	33779	**0.748**	2	0.22
neos-631710	14.21%	2	14.21%	1.000	2	1.000	0	–
	8.90%	4	8.90%	1.000	4	1.000	0	–
	14.21%	3	14.21%	1.000	3	1.000	0	–
neos-662469	0.00%	61996	0.01%	1.000	59651	0.962	2350	1.04
	0.01%	60229	0.00%	1.000	50627	0.841	1435	1.01
	0.01%	58756	0.01%	1.000	56995	0.970	3004	1.03
neos-787933	1.35	1	1.37	1.015	1	1.000	0	–
	1.38	1	1.39	1.007	1	1.000	0	–
	1.34	1	1.41	*1.052*	1	1.000	0	–
neos-827175	6.08	1	6.10	1.003	1	1.000	0	–
	8.24	1	8.21	0.996	1	1.000	0	–
	10.18	1	10.23	1.005	1	1.000	0	–
neos-848589	32.79%	254	32.15%	1.000	256	1.008	1	0.00
	42.57%	152	42.95%	1.000	148	0.974	0	–
	46.27%	106	46.27%	1.000	106	1.000	1	0.00
neos-860300	17.20	2	17.27	1.004	2	1.000	0	–
	13.35	2	13.35	1.000	2	1.000	0	–
	23.15	3	23.18	1.001	3	1.000	0	–
neos-873061	9.28%	155	9.28%	1.000	155	1.000	0	–
	7.72%	148	7.72%	1.000	148	1.000	1	0.28
	8.12%	168	8.12%	1.000	168	1.000	1	0.73
neos-911970	1.05%	1400844	1.05%	1.000	1400854	1.000	155	1.58
	2.49%	1814171	2.49%	1.000	1814127	1.000	963	2.56
	0.06%	11518168	0.06%	1.000	11460910	0.995	83	1.74
neos-933966	0.31%	1275	1374.28	**0.191**	138	**0.108**	2	0.31
	1567.83	476	848.27	**0.541**	38	**0.080**	2	0.31
	1294.09	86	2180.73	*1.685*	283	*3.291*	2	0.31
neos-950242	100.00%	9254	100.00%	1.000	9288	1.004	0	–
	100.00%	8343	100.00%	1.000	8446	1.012	0	–
	100.00%	15577	100.00%	1.000	15629	1.003	0	–
neos-957323	86.44	2	86.06	0.996	2	1.000	0	–
	110.13	5	110.59	1.004	5	1.000	0	–
	79.86	2	80.10	1.003	2	1.000	0	–
neos-960392	875.61	15	881.09	1.006	15	1.000	0	–
	1448.19	102	1439.63	0.994	102	1.000	0	–
	1365.59	403	1363.87	0.999	403	1.000	0	–
neos17	25.68	22460	25.95	1.011	22460	1.000	0	–
	9.26	5644	9.39	1.014	5644	1.000	0	–
	9.63	6376	9.84	1.022	6376	1.000	3	0.74

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
neos5	1010.47	3292114	1007.54	0.997	3292114	1.000	0	–
	1224.74	4202380	1234.24	1.008	4202380	1.000	0	–
	1182.22	4100005	1183.51	1.001	4100005	1.000	0	–
neos859080	0.50	792	0.50	1.000	792	1.000	0	–
	0.55	655	0.54	0.982	655	1.000	0	–
	0.53	565	0.55	1.038	565	1.000	0	–
neos8	1.98	1	1.95	0.985	1	1.000	1	0.98
	1.86	1	1.89	1.016	1	1.000	0	–
	1.83	1	1.83	1.000	1	1.000	0	–
net12	1900.74	1237	1842.42	0.969	1211	0.979	41	0.31
	1748.89	1895	1631.28	**0.933**	1816	0.958	85	0.30
	1562.61	1695	1561.43	0.999	1695	1.000	33	0.30
netdiversion	842.53	43	848.00	1.006	43	1.000	0	–
	2369.77	88	2364.82	0.998	88	1.000	0	–
	1086.77	27	1087.12	1.000	27	1.000	0	–
nexp-150-20-8-5	3491.23	5786	3539.59	1.014	5786	1.000	0	–
	3633.98	7166	3635.13	1.000	7166	1.000	0	–
	0.83%	13146	0.83%	1.000	13054	0.993	1	1.01
ns1116954	∞	32	∞	1.000	32	1.000	0	–
	∞	57	∞	1.000	57	1.000	0	–
	∞	73	∞	1.000	75	1.027	0	–
ns1208400	418.27	2004	419.49	1.003	2004	1.000	0	–
	681.63	2339	683.06	1.002	2339	1.000	0	–
	1071.93	2315	1074.09	1.002	2315	1.000	0	–
ns1644855	7.37%	36	7.37%	1.000	36	1.000	0	–
	7.37%	79	7.37%	1.000	79	1.000	0	–
	976.27	1	974.47	0.998	1	1.000	0	–
ns1760995	58.41%	1	58.41%	1.000	1	1.000	0	–
	71.46%	1	71.46%	1.000	1	1.000	0	–
	49.34%	1	48.93%	1.000	1	1.000	0	–
ns1830653	287.45	14558	287.45	1.000	14558	1.000	0	–
	133.82	7527	134.33	1.004	7527	1.000	0	–
	147.17	7267	148.24	1.007	7267	1.000	0	–
ns1952667	∞	59183	∞	1.000	52208	0.882	22770	0.98
	1283.87	9508	1392.38	*1.085*	9508	1.000	2910	0.99
	920.29	4900	968.90	*1.053*	4900	1.000	1183	0.95
nu25-pr12	5.27	53	5.36	1.017	53	1.000	5	0.76
	6.01	66	6.11	1.017	66	1.000	8	1.16
	6.02	16	6.05	1.005	16	1.000	5	0.77
nursesched-medium-hint03	1657.78%	1115	1657.78%	1.000	1100	0.987	0	–
	3021.25%	2083	3021.25%	1.000	2050	0.984	1	0.51
	1077.84%	1128	1077.84%	1.000	1121	0.994	0	–
nursesched-sprint02	141.76	370	142.08	1.002	370	1.000	0	–
	85.07	409	85.18	1.001	409	1.000	0	–
	67.95	222	67.71	0.996	222	1.000	0	–
nw04	38.20	6	37.93	0.993	6	1.000	0	–
	31.45	5	31.39	0.998	5	1.000	0	–
	35.06	6	35.16	1.003	6	1.000	0	–
opm2-z10-s4	24.70%	996	24.70%	1.000	1000	1.004	0	–
	27.76%	583	27.76%	1.000	586	1.005	0	–
	26.96%	1015	26.96%	1.000	1015	1.000	0	–
p200x1188c	3.54	2	3.53	0.997	2	1.000	0	–
	3.98	3	3.96	0.995	3	1.000	0	–
	3.61	2	3.62	1.003	2	1.000	0	–
peg-solitaire-a3	∞	5762	∞	1.000	5752	0.998	0	–
	∞	3581	∞	1.000	3557	0.993	0	–

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
	∞	3962	∞	1.000	3969	1.002	0	–
pg5_34	1147.46	145007	1173.22	1.022	148717	1.026	10834	0.09
	1093.92	134018	1134.07	1.037	144543	*1.079*	14587	0.07
	964.61	125934	1085.15	*1.125*	121673	0.966	16980	0.07
pg	106.20	2983	101.85	0.959	2687	**0.901**	429	0.08
	86.34	1354	86.23	0.999	1372	1.013	379	0.10
	105.03	2596	107.44	1.023	2311	**0.890**	705	0.08
physicians ched3-3	∞	412	∞	1.000	415	1.007	0	–
	∞	313	∞	1.000	313	1.000	0	–
	∞	359	∞	1.000	361	1.006	0	–
physicians ched6-2	124.53	377	124.81	1.002	377	1.000	0	–
	459.96	2804	462.02	1.004	2804	1.000	0	–
	44.81	1	44.74	0.998	1	1.000	0	–
piperout-08	821.29	149	797.03	0.970	130	**0.872**	24	1.29
	606.63	552	606.54	1.000	552	1.000	0	–
	944.95	788	923.85	0.978	596	**0.756**	15	1.38
piperout-27	140.27	2	140.11	0.999	2	1.000	0	–
	272.83	566	275.91	1.011	566	1.000	0	–
	330.74	72	332.32	1.005	72	1.000	6	0.75
pk1	108.50	306046	107.55	0.991	301100	0.984	118	0.59
	108.33	316310	109.16	1.008	317026	1.002	23	0.61
	114.96	338401	112.34	0.977	328715	0.971	76	0.62
proteindesign121hz512p9	9.60%	579	9.60%	1.000	591	1.021	56	0.84
	7.94%	443	7.94%	1.000	440	0.993	47	0.86
	26.02%	598	26.02%	1.000	593	0.992	81	0.86
proteindesign122trx11p8	1.95%	3	1.95%	1.000	3	1.000	21	0.74
	1.91%	8	1.91%	1.000	8	1.000	124	0.33
	1.93%	17	1.93%	1.000	17	1.000	26	0.72
qap10	87.80	3	87.99	1.002	3	1.000	0	–
	111.64	5	111.82	1.002	5	1.000	0	–
	196.87	15	197.87	1.005	15	1.000	0	–
radiationm18-12-05	9.31%	426457	12.99%	1.000	479812	1.125	1044	0.59
	14.84%	781939	0.05%	1.000	750150	0.959	2527	0.63
	0.02%	513263	1.89%	1.000	551080	1.074	1609	0.61
radiationm40-10-02	67.02%	52863	67.02%	1.000	53316	1.009	19	0.42
	57.74%	27496	57.74%	1.000	27109	0.986	15	0.42
	22.69%	98439	22.69%	1.000	99008	1.006	109	0.39
rail01	2.74%	201	2.74%	1.000	200	0.995	0	–
	25.21%	183	25.21%	1.000	182	0.995	0	–
	7.32%	185	7.32%	1.000	183	0.989	0	–
rail02	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
rail507	156.61	623	156.67	1.000	623	1.000	0	–
	179.24	783	180.04	1.004	783	1.000	0	–
	192.93	771	193.43	1.003	771	1.000	0	–
ran14x18-disj-8	1875.03	579341	2109.62	*1.125*	656920	*1.134*	5926	0.87
	1631.15	596062	1785.31	*1.095*	564900	**0.948**	5346	0.86
	1762.48	651842	1694.59	0.961	593570	**0.911**	5795	0.88
rd-rplusc-21	≥ 10000%	632597	≥ 10000%	1.000	484631	0.766	6281	1.00
	≥ 10000%	518812	≥ 10000%	1.000	737139	1.421	8674	0.95
	≥ 10000%	787540	≥ 10000%	1.000	763715	0.970	5071	0.95
reblock115	4385.16	704168	4390.48	1.001	704168	1.000	12	1.24
	6590.03	882785	6605.46	1.002	882785	1.000	19	1.22
	5883.59	832788	5894.68	1.002	832788	1.000	25	1.29
rmatr100-p10	163.96	809	166.48	1.015	809	1.000	0	–

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Table A.5: Detailed computational results on Miplib 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
	161.56	822	162.84	1.008	822	1.000	0	–
	159.59	827	160.62	1.006	827	1.000	0	–
rmatr200-p5	22.40%	428	22.40%	1.000	421	0.984	0	–
	19.56%	424	19.56%	1.000	423	0.998	0	–
	21.08%	393	21.08%	1.000	403	1.025	0	–
rocI-4-11	639.46	12970	638.21	0.998	12970	1.000	29	0.85
	1001.23	17602	1001.80	1.001	17602	1.000	43	0.80
	497.78	9550	498.07	1.001	9550	1.000	52	0.73
rocII-5-11	108.31%	3304	108.52%	1.000	3399	1.029	131	0.67
	152.76%	2791	109.87%	1.000	2764	0.990	119	0.69
	109.22%	2858	109.11%	1.000	2522	0.882	72	0.74
rococoB10-011000	13.70%	151342	13.71%	1.000	151103	0.998	0	–
	15.08%	143535	15.09%	1.000	143253	0.998	0	–
	12.80%	153848	12.80%	1.000	153839	1.000	0	–
rococoC10-001000	766.14	53303	765.76	1.000	53303	1.000	0	–
	843.78	63090	851.99	1.010	63090	1.000	0	–
	1616.05	162527	1626.91	1.007	162527	1.000	0	–
roi2alpha3n4	1416.86	12529	1424.80	1.006	12529	1.000	0	–
	1926.56	17446	1940.46	1.007	17446	1.000	0	–
	1475.88	13303	1486.54	1.007	13303	1.000	0	–
roi5alpha10n8	35.37%	6060	35.37%	1.000	5989	0.988	0	–
	40.38%	6271	40.36%	1.000	6346	1.012	0	–
	32.14%	6790	32.14%	1.000	6789	1.000	0	–
roll3000	36.75	1986	36.86	1.003	1986	1.000	17	1.06
	38.84	2149	38.91	1.002	2149	1.000	55	1.10
	59.94	3736	60.26	1.005	3736	1.000	18	1.15
s100	14.04%	18	5.53%	1.000	20	1.111	0	–
	29.84%	17	29.84%	1.000	17	1.000	0	–
	1.06%	22	1.06%	1.000	22	1.000	0	–
s250r10	0.27%	23455	0.28%	1.000	22897	0.976	0	–
	6127.84	45426	6366.45	1.039	45426	1.000	0	–
	0.22%	34654	0.23%	1.000	31811	0.918	0	–
satellites2-40	∞	19	∞	1.000	19	1.000	0	–
	∞	4	∞	1.000	4	1.000	0	–
	70.59%	33	70.59%	1.000	33	1.000	1	0.26
satellites2-60-fs	∞	33	∞	1.000	33	1.000	1	0.01
	∞	137	∞	1.000	137	1.000	1	0.23
	∞	28	∞	1.000	28	1.000	0	–
savsched1	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
sct2	0.03%	679457	0.03%	1.000	600226	0.883	1243	0.47
	0.03%	830638	0.05%	1.000	659682	0.794	202	0.53
	0.03%	1096527	0.03%	1.000	994927	0.907	311	0.64
seymour1	90.48	1627	90.45	1.000	1627	1.000	0	–
	68.11	1466	67.90	0.997	1466	1.000	0	–
	71.89	1822	72.05	1.002	1822	1.000	0	–
seymour	0.66%	242385	0.66%	1.000	242500	1.000	0	–
	0.68%	222870	0.68%	1.000	222209	0.997	0	–
	0.74%	226598	0.74%	1.000	225373	0.995	0	–
sing326	0.15%	11732	0.15%	1.000	11755	1.002	400	0.69
	0.17%	8401	0.17%	1.000	8196	0.976	395	0.68
	0.31%	8062	0.32%	1.000	7997	0.992	546	0.63
sing44	0.45%	5563	0.45%	1.000	5531	0.994	169	0.80
	0.19%	7451	0.19%	1.000	7349	0.986	290	0.67
	0.27%	2269	0.27%	1.000	2267	0.999	261	0.69

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
snp-02-004-104	0.00%	15069	0.00%	1.000	14561	0.966	734	0.00
	0.00%	18040	0.00%	1.000	18040	1.000	884	0.00
	0.00%	19680	0.00%	1.000	19680	1.000	375	0.00
sorrell3	43.81%	41078	43.81%	1.000	41208	1.003	0	–
	35.59%	39485	35.59%	1.000	39514	1.001	0	–
	19.11%	8947	19.11%	1.000	8801	0.984	0	–
sp150x300d	3.96	3472	3.96	1.000	3472	1.000	0	–
	3.12	2569	3.12	1.000	2569	1.000	0	–
	1.31	848	1.29	0.985	848	1.000	0	–
sp97ar	0.98%	15805	0.98%	1.000	15747	0.996	0	–
	1.02%	22713	1.02%	1.000	22961	1.011	0	–
	1.53%	24818	1.53%	1.000	24828	1.000	0	–
sp98ar	1.43%	71917	1.43%	1.000	71746	0.998	0	–
	0.48%	67062	0.48%	1.000	67060	1.000	0	–
	0.98%	71914	0.98%	1.000	71271	0.991	0	–
splice1k1	309.20%	514	309.20%	1.000	513	0.998	0	–
	376.26%	581	376.10%	1.000	594	1.022	0	–
	358.74%	837	358.74%	1.000	834	0.996	0	–
square41	109.98%	30	109.98%	1.000	30	1.000	12	0.94
	89.32%	38	89.32%	1.000	37	0.974	11	0.85
	92.32%	28	92.32%	1.000	28	1.000	0	–
square47	231.21%	4	231.21%	1.000	4	1.000	0	–
	117.00%	13	117.00%	1.000	13	1.000	0	–
	231.21%	1	231.21%	1.000	1	1.000	0	–
supportcase10	803.51%	1	803.51%	1.000	1	1.000	0	–
	989.07%	1	989.07%	1.000	1	1.000	0	–
	1054.36%	1	1054.36%	1.000	1	1.000	0	–
supportcase12	1.31%	1473	1.31%	1.000	1463	0.993	46	0.42
	1.35%	2297	1.35%	1.000	2297	1.000	199	0.78
	0.97%	1502	1.30%	1.000	1505	1.002	118	0.74
supportcase18	3.84%	422401	3.84%	1.000	419350	0.993	0	–
	5.96%	238082	5.96%	1.000	237591	0.998	0	–
	3.84%	199099	3.84%	1.000	198815	0.999	0	–
supportcase19	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
	∞	1	∞	1.000	1	1.000	0	–
supportcase22	∞	51	∞	1.000	51	1.000	0	–
	∞	18	∞	1.000	18	1.000	0	–
	∞	66	∞	1.000	66	1.000	0	–
supportcase26	9.30%	8027495	8.94%	1.000	8135621	1.013	22612	0.71
	4654.53	5763770	5238.22	*1.125*	6761735	*1.173*	13464	0.66
	3870.89	4822910	4487.28	*1.159*	5497025	*1.140*	11349	0.58
supportcase33	1593.48	13435	1598.38	1.003	12756	**0.949**	415	0.48
	1752.51	8942	1600.98	**0.914**	7176	**0.803**	89	0.43
	671.18	3786	682.16	1.016	3786	1.000	158	0.37
supportcase40	787.68	6335	786.50	0.999	6335	1.000	308	0.14
	1057.65	9809	946.94	**0.895**	7991	**0.815**	220	0.16
	1002.89	9904	797.74	**0.795**	6970	**0.704**	175	0.15
supportcase42	0.38%	304886	0.38%	1.000	305571	1.002	433	0.00
	0.10%	380785	0.10%	1.000	380155	0.998	997	0.00
	0.35%	471537	0.35%	1.000	467610	0.992	766	0.00
supportcase6	9.13%	19697	9.13%	1.000	18980	0.964	0	–
	8.35%	18186	8.41%	1.000	17726	0.975	0	–
	9.72%	17735	9.72%	1.000	17709	0.999	0	–
supportcase7	183.36	59	179.98	0.982	59	1.000	14	0.04
	193.18	45	193.62	1.002	45	1.000	24	0.09

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Table A.5: Detailed computational results on MIPLIB 2017 benchmark with and without applying c-MIR function.

	mir-procedure disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	MIR	$MIRnnz_Q$
	208.38	32	210.25	1.009	32	1.000	53	0.06
swath1	17.54	281	21.09	*1.202*	281	1.000	4	0.31
	14.91	245	17.34	*1.163*	245	1.000	0	–
	16.43	292	19.82	*1.206*	292	1.000	2	0.27
swath3	198.93	28316	226.20	*1.137*	28316	1.000	42	0.42
	158.44	21837	182.91	*1.154*	21837	1.000	40	0.41
	374.36	74192	427.45	*1.142*	74192	1.000	74	0.32
tbfp-network	2339.45	574	2356.81	1.007	574	1.000	0	–
	1691.29	71	1683.80	0.996	71	1.000	0	–
	1086.54	99	1088.57	1.002	99	1.000	0	–
thor50dday	23.30%	113	23.30%	1.000	95	0.841	1	0.70
	21.49%	11	21.49%	1.000	12	1.091	0	–
	14.80%	31	14.80%	1.000	34	1.097	0	–
timtab1	73.22	62076	73.73	1.007	64175	1.034	1556	0.82
	67.45	51540	67.90	1.007	51540	1.000	1122	0.82
	69.67	51236	70.92	1.018	55054	*1.075*	1687	0.85
tr12-30	696.54	475823	606.97	**0.871**	423661	**0.890**	5284	0.64
	719.59	515503	650.32	**0.904**	475420	**0.922**	7899	0.69
	406.41	226138	397.52	0.978	213946	**0.946**	2847	0.69
traininstance2	∞	66539	∞	1.000	67099	1.008	662	0.94
	∞	48459	∞	1.000	52063	1.074	1188	0.96
	6286.13%	73306	6286.13%	1.000	73138	0.998	696	0.95
traininstance6	794.89%	279783	634.16%	1.000	456248	1.631	6464	0.94
	648.14%	357229	626.92%	1.000	347529	0.973	4040	0.95
	561.81%	459177	520.12%	1.000	454368	0.990	5508	0.94
trento1	0.07%	58820	0.07%	1.000	57766	0.982	145	1.02
	0.10%	51318	0.10%	1.000	51033	0.994	83	0.81
	4.72%	44905	1.67%	1.000	35013	0.780	97	0.94
triptim1	1110.12	8	1099.43	0.990	8	1.000	0	–
	745.67	7	747.73	1.003	7	1.000	0	–
	1060.52	8	1065.09	1.004	8	1.000	0	–
uccase12	0.00%	92859	0.00%	1.000	77800	0.838	873	0.10
	0.00%	91202	0.00%	1.000	91468	1.003	926	0.11
	0.00%	82292	0.00%	1.000	98605	1.198	657	0.11
uccase9	1.98%	496	1.98%	1.000	498	1.004	89	0.39
	1.48%	1145	1.48%	1.000	1166	1.018	69	0.34
	2.82%	550	2.82%	1.000	550	1.000	72	0.38
uct-subprob	1111.26	44339	1102.62	0.992	44339	1.000	0	–
	1628.25	59559	1631.60	1.002	59559	1.000	0	–
	2491.33	95674	2506.36	1.006	95674	1.000	0	–
unitcal_7	271.15	89	272.59	1.005	89	1.000	53	0.17
	297.80	180	298.12	1.001	180	1.000	117	0.20
	384.00	436	387.18	1.008	436	1.000	113	0.23
var-smallemery-m6j6	0.93%	567102	0.93%	1.000	568323	1.002	184	2.09
	0.87%	657094	0.87%	1.000	656232	0.999	18	1.72
	6758.47	683202	6729.45	0.996	683202	1.000	2235	1.65
wachplan	2328.24	219938	2340.84	1.005	219938	1.000	3	0.52
	3378.02	301974	3419.67	1.012	302179	1.001	4	0.26
	2340.68	198054	2343.95	1.001	198054	1.000	0	–

Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
30n20b8	149.54	171	149.68	1.001	171	1.000	0	0
	582.65	1959	623.60	*1.070*	1999	1.020	0	290
	659.88	3242	693.56	*1.051*	3499	*1.079*	0	73
50v-10	1.55%	825087	1.69%	1.000	829421	1.005	0	154395
	1.31%	912826	1.15%	1.000	867997	0.951	0	177166
	1.16%	826673	1.37%	1.000	833134	1.008	0	161381
CMS750_4	185.66	2028	185.73	1.000	2028	1.000	0	0
	371.41	3254	370.72	0.998	3254	1.000	0	0
	474.76	13518	473.12	0.997	13518	1.000	0	0
academictimetablesmall	∞	2465	∞	1.000	2315	0.939	0	124
	∞	2803	∞	1.000	3505	1.250	0	165
	∞	2707	∞	1.000	2681	0.990	0	136
air05	40.50	597	40.07	0.989	648	*1.085*	0	70
	40.16	674	36.54	**0.910**	716	*1.062*	0	107
	38.17	417	30.22	**0.792**	282	**0.676**	0	152
app1-1	3.52	2	3.53	1.003	2	1.000	0	0
	4.90	3	4.94	1.008	3	1.000	0	0
	4.17	6	4.17	1.000	6	1.000	0	0
app1-2	642.45	33	642.80	1.001	33	1.000	0	0
	790.19	20	789.47	0.999	20	1.000	4	0
	619.92	20	618.36	0.997	20	1.000	2	0
assign1-5-8	4.61%	6907107	4.74%	1.000	5736357	0.831	0	396422
	4.61%	6309496	4.54%	1.000	6813236	1.080	0	480273
	4.78%	6421846	4.80%	1.000	6333262	0.986	0	441734
atlanta-ip	7.14%	18001	3.60%	1.000	18533	1.030	0	184
	3.68%	20488	3.81%	1.000	21153	1.032	3	240
	2.49%	22976	4.27%	1.000	30903	1.345	3	287
b1c1s1	17.19%	47377	17.13%	1.000	35962	0.759	123	39
	20.72%	11994	18.36%	1.000	21112	1.760	67	12
	18.10%	19088	17.69%	1.000	18673	0.978	76	75
bab2	1.32%	3984	1.29%	1.000	3473	0.872	0	108
	1.97%	3402	2.44%	1.000	3262	0.959	0	111
	∞	2004	∞	1.000	1981	0.989	0	0
bab6	0.58%	5249	0.58%	1.000	4790	0.913	0	226
	1.14%	3189	1.14%	1.000	3258	1.022	0	39
	1.94%	4622	1.94%	1.000	4779	1.034	0	153
beasleyC3	31.74	83	31.56	0.994	83	1.000	0	0
	17.39	2	17.35	0.998	2	1.000	0	0
	45.80	461	47.20	1.031	453	0.983	0	142
binkar10_1	31.70	2560	31.34	0.989	2560	1.000	0	0
	29.11	2246	29.22	1.004	2246	1.000	0	0
	28.80	2509	28.71	0.997	2509	1.000	0	0
blp-ar98	0.43%	196402	0.27%	1.000	238231	1.213	0	20326
	0.23%	217611	0.33%	1.000	207500	0.954	0	19963
	0.23%	207939	0.32%	1.000	229423	1.103	0	20227
blp-ic98	1.51%	281795	1.38%	1.000	304769	1.082	0	32075
	2.26%	288443	2.41%	1.000	254061	0.881	0	20280
	2.06%	268446	2.11%	1.000	278188	1.036	0	26047
bnatt400	966.88	6821	970.91	1.004	6821	1.000	0	0
	1102.20	6346	1105.02	1.003	6346	1.000	0	0
	743.13	5500	745.15	1.003	5500	1.000	0	0
bnatt500	4360.93	29526	4368.17	1.002	29526	1.000	0	0
	6313.03	38962	6333.06	1.003	38962	1.000	0	0
	4990.78	29029	4996.90	1.001	29029	1.000	0	0
bppc4-08	1.92%	700039	1.92%	1.000	797503	1.139	0	330814

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
	1.92%	790062	1.92%	1.000	938927	1.188	1	82475
	1.92%	713373	1.92%	1.000	793397	1.112	6	9683
brazil3	58.33%	3691	3360.46	**0.467**	2570	**0.696**	0	808
	66.63%	4714	4252.19	**0.591**	2347	**0.498**	0	921
	2726.35	1732	3785.08	*1.388*	3302	*1.906*	0	504
buildingenergy	0.13%	96	0.13%	1.000	96	1.000	0	0
	0.15%	85	0.15%	1.000	85	1.000	0	0
	0.13%	12	0.13%	1.000	12	1.000	0	0
cbs-cta	40.06	1	40.27	1.005	1	1.000	0	0
	314.43	31	314.10	0.999	31	1.000	0	0
	35.85	1	35.77	0.998	1	1.000	0	0
chromaticindex1024-7	33.33%	968	33.33%	1.000	964	0.996	0	0
	33.33%	1190	33.33%	1.000	1171	0.984	0	0
	6450.57	757	6429.72	0.997	757	1.000	0	0
chromaticindex512-7	1186.41	361	1172.37	0.988	361	1.000	0	0
	3700.18	3133	3689.97	0.997	3133	1.000	0	0
	33.33%	40589	33.33%	1.000	40579	1.000	0	0
cmflsp50-24-8-8	3.98%	35922	3.98%	1.000	36090	1.005	4	0
	2.00%	83678	1.99%	1.000	85475	1.021	5	0
	4.86%	37970	4.86%	1.000	37790	0.995	6	1
co-100	2.13%	49439	1.74%	1.000	54008	1.092	0	10588
	2.83%	24888	91.77%	1.000	7012	0.282	0	3700
	2.98%	10921	3.18%	1.000	10565	0.967	1	4373
cod105	47.77%	6892	47.57%	1.000	7261	1.054	0	2007
	48.00%	6864	48.00%	1.000	6829	0.995	0	1967
	48.07%	6601	48.07%	1.000	6601	1.000	0	2170
comp07-2idx	600.00%	3934	966.67%	1.000	3996	1.016	0	293
	633.33%	2475	2800.00%	1.000	743	0.300	0	254
	866.67%	2862	1716.67%	1.000	1449	0.506	0	198
comp21-2idx	244.83%	9501	247.43%	1.000	10931	1.151	0	1035
	228.25%	9080	195.50%	1.000	9835	1.083	0	1576
	225.16%	11555	248.72%	1.000	11711	1.014	0	957
cost266-UUE	5067.55	431331	4923.15	0.972	375684	**0.871**	549	0
	3361.61	257227	3728.83	*1.109*	294630	*1.145*	899	0
	4827.79	427959	4067.72	**0.843**	306702	**0.717**	735	0
cryptanalysiskb128n5obj14	∞	111	∞	1.000	110	0.991	0	0
	∞	56	∞	1.000	59	1.054	0	0
	∞	91	∞	1.000	90	0.989	0	0
cryptanalysiskb128n5obj16	∞	103	∞	1.000	104	1.010	0	0
	2794.79	37	2790.65	0.999	37	1.000	0	0
	∞	97	∞	1.000	97	1.000	0	0
csched007	2423.01	170977	2327.77	0.961	187288	*1.095*	0	27804
	3761.60	303028	2613.95	**0.695**	220934	**0.729**	0	31144
	3193.45	251998	3393.08	*1.063*	247755	0.983	0	33239
csched008	1.16%	578225	2.81%	1.000	455870	0.788	0	85766
	1.74%	933994	2.33%	1.000	694455	0.744	0	201461
	2824.43	262789	5772.95	*2.044*	546382	*2.079*	0	175259
cvs16r128-89	21.28%	26025	23.28%	1.000	67980	2.612	0	11794
	20.14%	31825	22.61%	1.000	34973	1.099	0	9091
	22.24%	18170	23.01%	1.000	47219	2.599	0	10489
dano3_3	144.34	10	143.70	0.996	10	1.000	0	0
	142.93	14	142.65	0.998	14	1.000	0	0
	125.01	17	124.56	0.996	17	1.000	0	0
dano3_5	638.76	276	635.04	0.994	276	1.000	0	0
	285.45	159	285.81	1.001	159	1.000	4	0
	286.05	140	285.94	1.000	140	1.000	0	0

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
decomp2	2.43	1	2.39	0.984	1	1.000	0	0
	2.51	1	2.42	0.964	1	1.000	0	0
	2.42	1	2.50	1.033	1	1.000	0	0
drayage-100-23	16.52	32	16.43	0.995	32	1.000	0	0
	19.73	48	19.52	0.989	48	1.000	0	0
	13.56	16	13.50	0.996	16	1.000	0	0
drayage-25-23	0.07%	838013	0.07%	1.000	720814	0.860	0	28888
	0.07%	735476	0.07%	1.000	790871	1.075	0	56406
	0.07%	645482	6941.84	0.964	552534	**0.856**	0	29536
dws008-01	49.94%	161878	44.84%	1.000	144766	0.894	13	2563
	47.11%	139898	44.28%	1.000	157395	1.125	8	3232
	51.83%	146064	52.63%	1.000	153108	1.048	7	3808
eil33-2	96.65	501	81.20	**0.840**	343	**0.685**	0	2699
	93.48	467	101.92	*1.090*	395	**0.846**	0	2273
	90.81	599	105.72	*1.164*	541	**0.903**	0	2593
eilA101-2	18.35%	11303	20.05%	1.000	11110	0.983	0	6659
	14.26%	10736	13.20%	1.000	12688	1.182	0	9758
	8.77%	12629	13.37%	1.000	13480	1.067	0	8679
enlight_hard	0.50	1	0.50	1.000	1	1.000	0	0
	0.50	1	0.50	1.000	1	1.000	0	0
	0.50	1	0.50	1.000	1	1.000	0	0
ex10	491.38	1	493.80	1.005	1	1.000	0	0
	497.33	1	497.94	1.001	1	1.000	0	0
	577.73	1	581.12	1.006	1	1.000	0	0
ex9	28.59	1	27.98	0.979	1	1.000	0	0
	27.27	1	27.30	1.001	1	1.000	0	0
	27.35	1	27.02	0.988	1	1.000	0	0
exp-1-500-5-5	2.29	1	2.28	0.996	1	1.000	0	0
	2.23	1	2.22	0.996	1	1.000	0	0
	2.24	1	2.21	0.987	1	1.000	0	0
fast0507	310.09	1346	322.23	1.039	1284	0.954	0	499
	294.63	1481	280.17	0.951	1223	**0.826**	0	574
	264.35	1019	365.44	*1.382*	1711	*1.679*	0	628
fastxgemm-n2r6s0t2	4764.24	1133328	4702.82	0.987	1118937	0.987	0	10346
	3160.65	753635	4017.11	*1.271*	1012967	*1.344*	0	8655
	4161.96	1036974	3129.08	**0.752**	769500	**0.742**	0	1400
fhnw-binpack4-48	∞	4052201	∞	1.000	4040499	0.997	0	0
	∞	3547482	∞	1.000	3525851	0.994	0	0
	∞	3418593	∞	1.000	3413924	0.999	0	0
fhnw-binpack4-4	∞	14763749	∞	1.000	14733968	0.998	0	0
	∞	14074973	∞	1.000	13981261	0.993	0	0
	∞	11745635	∞	1.000	11607995	0.988	0	0
fiball	464.37	4111	465.55	1.003	4111	1.000	0	0
	444.67	3521	447.14	1.006	3521	1.000	0	1
	501.66	5672	499.03	0.995	5672	1.000	0	7
gen-ip002	1656.56	6963244	1315.68	**0.794**	5856334	**0.841**	0	279
	1291.40	5478569	1295.56	1.003	5478569	1.000	0	0
	1276.81	5583912	1271.92	0.996	5583912	1.000	0	0
gen-ip054	3075.10	15245360	3047.64	0.991	15245360	1.000	0	0
	2551.41	12476019	2530.93	0.992	12476019	1.000	0	0
	3374.80	16438070	3381.24	1.002	16438070	1.000	0	0
germanrr	1.31%	3431	1.46%	1.000	3418	0.996	0	389
	1.48%	5813	2.11%	1.000	2851	0.490	0	525
	1.93%	3657	1.94%	1.000	3559	0.973	0	541
gfd-schedulen180f7d50m30k18	∞	4	∞	1.000	4	1.000	0	0
	∞	9	∞	1.000	8	0.889	0	0

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
	∞	10	∞	1.000	10	1.000	0	0
glass-sc	2687.32	240771	2655.26	0.988	241329	1.002	0	22536
	3226.08	289204	3214.67	0.996	289206	1.000	0	27228
	2855.82	251112	2819.06	0.987	251112	1.000	0	24774
glass4	2961.34	2175685	4008.75	*1.354*	2705421	*1.243*	8368	3633
	1734.58	1609175	2392.84	*1.379*	1888717	*1.174*	5279	2200
	3446.14	2337682	2212.84	**0.642**	1599046	**0.684**	2522	1558
gmu-35-40	0.03%	2446361	0.05%	1.000	2051936	0.839	3	120300
	0.04%	2099536	0.03%	1.000	2099939	1.000	5	95182
	0.02%	2456805	0.03%	1.000	1381092	0.562	1	94971
gmu-35-50	0.01%	1354235	0.02%	1.000	1317781	0.973	43	139924
	0.04%	1049496	0.03%	1.000	1247342	1.189	10	83282
	0.05%	1032089	0.04%	1.000	1016723	0.985	3	69768
graph20-20-1rand	170.36%	10337	163.73%	1.000	6171	0.597	0	582
	163.28%	13477	165.38%	1.000	8277	0.614	1	1259
	165.75%	7264	172.66%	1.000	7513	1.034	0	999
graphdraw-domain	813.34	1597956	1010.47	*1.242*	1823083	*1.141*	0	2246
	1082.01	1869096	1122.85	1.038	1941578	1.039	0	3630
	1619.84	3139503	1664.67	1.028	2907888	**0.926**	0	2339
h80x6320d	69.58	4	69.54	0.999	4	1.000	0	3
	84.66	8	86.17	1.018	10	*1.250*	0	2
	85.95	5	86.62	1.008	5	1.000	0	2
highschool1-aigio	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
hypothyroid-k1	19.72	1	20.04	1.016	1	1.000	0	0
	19.69	1	19.99	1.015	1	1.000	0	0
	20.09	1	20.16	1.003	1	1.000	0	0
ic97_potential	0.76%	7316855	0.84%	1.000	7214792	0.986	0	5223
	0.71%	6411766	0.75%	1.000	6107856	0.953	0	5125
	0.78%	7129049	0.86%	1.000	7579116	1.063	0	6662
icir97_tension	0.07%	3168421	0.07%	1.000	3185773	1.005	0	0
	0.05%	2775918	0.05%	1.000	2776552	1.000	0	0
	0.08%	2726949	0.08%	1.000	2729235	1.001	0	0
irish-electricity	∞	93	∞	1.000	93	1.000	0	0
	18.81%	1362	18.43%	1.000	1317	0.967	32	0
	∞	1333	∞	1.000	1333	1.000	21	0
irp	12.07	5	12.51	1.036	6	*1.200*	0	18
	12.02	4	12.05	1.002	4	1.000	0	3
	12.21	4	12.58	1.030	5	*1.250*	0	20
istanbul-no-cutoff	153.32	347	154.02	1.005	347	1.000	0	0
	166.23	245	166.34	1.001	245	1.000	0	0
	285.04	475	285.14	1.000	475	1.000	0	0
k1mushroom	1847.86	7	1897.56	1.027	7	1.000	0	0
	1529.62	11	1583.93	1.036	11	1.000	0	0
	1298.65	3	1321.29	1.017	3	1.000	0	2
lectsched-5-obj	166.67%	148446	166.67%	1.000	148725	1.002	0	0
	120.00%	130915	120.00%	1.000	130812	0.999	0	0
	126.67%	65168	126.67%	1.000	64923	0.996	0	0
leo1	7.00%	91974	6.11%	1.000	80819	0.879	0	12149
	4.70%	59437	7.14%	1.000	34905	0.587	0	8365
	7.01%	81485	7.53%	1.000	45969	0.564	0	9683
leo2	∞	100359	∞	1.000	101616	1.013	1	35
	∞	131264	∞	1.000	110967	0.845	0	61
	∞	132093	∞	1.000	146706	1.111	0	1106
lotsize	0.55%	17847	0.67%	1.000	16786	0.941	1529	46

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
	0.94%	19920	0.88%	1.000	20493	1.029	1651	516
	0.53%	21271	0.70%	1.000	17911	0.842	1323	66
mad	∞	15657701	∞	1.000	8295624	0.530	0	194702
	∞	14489476	∞	1.000	14934806	1.031	0	176105
	∞	12926670	∞	1.000	15381075	1.190	0	171031
map10	1010.05	1637	1006.71	0.997	1637	1.000	0	0
	633.89	724	633.84	1.000	724	1.000	0	0
	797.63	965	792.96	0.994	965	1.000	0	0
map16715-04	2158.04	1933	2158.43	1.000	1933	1.000	0	0
	2336.90	2173	2335.51	0.999	2173	1.000	0	0
	2156.27	1990	2160.04	1.002	1990	1.000	0	0
markshare2	∞	6363355	∞	1.000	5827069	0.916	0	473529
	∞	5837837	∞	1.000	5581862	0.956	0	463495
	∞	5995287	∞	1.000	5052479	0.843	0	426947
markshare_4_0	139.43	1159084	72.47	**0.520**	612396	**0.528**	0	101
	174.69	1459529	70.48	**0.403**	589762	**0.404**	0	249
	188.56	1569373	85.88	**0.455**	719508	**0.458**	0	381
mas74	1776.06	5268095	1680.79	**0.946**	4932223	**0.936**	0	123857
	2335.34	8710934	2282.09	0.977	7992914	**0.918**	0	196722
	1338.68	4115864	1563.59	*1.168*	4674399	*1.136*	0	130366
mas76	139.27	419261	136.88	0.983	406104	0.969	0	1122
	168.64	525538	168.46	0.999	525538	1.000	0	22101
	150.32	450422	152.65	1.016	450422	1.000	0	337
mc11	148.49	6584	149.40	1.006	6484	0.985	12	1
	80.74	1474	80.39	0.996	1411	0.957	7	0
	98.44	2267	106.11	*1.078*	3386	*1.494*	64	0
mcsched	233.03	11746	318.21	*1.366*	11378	0.969	0	11
	344.61	14710	235.33	**0.683**	9846	**0.669**	0	23
	245.04	8130	306.32	*1.250*	12017	*1.478*	0	17
mik-250-20-75-4	52.56	23893	52.78	1.004	23893	1.000	0	0
	43.93	15175	43.96	1.001	15175	1.000	0	0
	52.11	20733	52.36	1.005	20733	1.000	0	0
milo-v12-6-r2-40-1	9.51%	330534	9.47%	1.000	189681	0.574	27	18887
	11.70%	214581	8.96%	1.000	323326	1.507	29	29850
	13.03%	246468	11.33%	1.000	417232	1.693	12	24987
momentum1	15.78%	74695	24.76%	1.000	94037	1.259	278	2935
	8.32%	188426	7.36%	1.000	91471	0.485	258	2937
	8.46%	133071	6.53%	1.000	188055	1.413	479	2508
mushroom-best	629.63	31333	579.50	**0.920**	27393	**0.874**	0	1970
	94.47%	85861	134.09%	1.000	94624	1.102	0	6006
	133.60%	98305	121.97%	1.000	98893	1.006	0	8499
mzzv11	209.59	594	210.71	1.005	484	**0.815**	0	116
	283.02	1116	263.08	**0.930**	987	**0.884**	0	50
	196.03	616	195.89	0.999	616	1.000	0	89
mzzv42z	176.70	396	175.26	0.992	415	1.048	0	33
	239.57	757	246.00	1.027	712	**0.941**	0	96
	308.36	770	306.34	0.993	719	**0.934**	0	52
n2seq36q	1218.36	6925	936.81	**0.769**	5438	**0.785**	0	1268
	1127.30	2937	1061.28	**0.941**	4712	*1.604*	0	810
	362.20	2014	1170.79	*3.232*	4632	*2.300*	0	844
n3div36	2.77%	194933	2.59%	1.000	213866	1.097	0	49323
	2.61%	179060	2.86%	1.000	207136	1.157	0	47721
	2.83%	179013	2.69%	1.000	202891	1.133	0	47069
n5-3	26.33	926	26.40	1.003	926	1.000	0	0
	27.63	971	27.79	1.006	971	1.000	0	0
	27.10	1087	27.09	1.000	1087	1.000	0	0

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
neos-1122047	10.01	1	9.92	0.991	1	1.000	0	0
	9.92	1	9.76	0.984	1	1.000	0	0
	10.09	1	9.70	0.961	1	1.000	0	0
neos-1171448	57.51	101	58.11	1.010	101	1.000	0	0
	5.17	1	5.16	0.998	1	1.000	0	0
	51.25	86	51.55	1.006	86	1.000	0	0
neos-1171737	1.04%	3926	1.04%	1.000	3912	0.996	0	0
	1.56%	3997	1.56%	1.000	4009	1.003	0	0
	1.30%	11743	1.30%	1.000	11719	0.998	0	0
neos-1354092	∞	613	∞	1.000	613	1.000	0	0
	∞	830	∞	1.000	820	0.988	0	0
	∞	639	∞	1.000	639	1.000	0	0
neos-1445765	43.66	133	43.72	1.001	133	1.000	0	147
	45.21	185	44.19	0.977	141	**0.762**	0	125
	45.16	125	44.74	0.991	125	1.000	0	146
neos-1456979	6.59%	59322	7.49%	1.000	39961	0.674	0	5198
	6.05%	39099	6.84%	1.000	38750	0.991	0	5469
	5.70%	58112	7.29%	1.000	31540	0.543	0	4153
neos-1582420	21.95	18	21.85	0.995	18	1.000	0	91
	10.94	9	10.92	0.998	9	1.000	0	23
	45.13	1201	55.49	*1.230*	1381	*1.150*	0	341
neos-2075418-temuka	7087.30	1	7024.05	0.991	1	1.000	0	0
	4565.54	1	4517.94	0.990	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-2657525-crna	∞	1528526	∞	1.000	3064132	2.005	0	148309
	∞	1961242	∞	1.000	3681104	1.877	0	121366
	∞	2021833	∞	1.000	2122332	1.050	1	105063
neos-2746589-doon	0.60%	41263	0.46%	1.000	55681	1.349	0	18019
	0.73%	19582	0.73%	1.000	30280	1.546	0	12358
	0.11%	149437	0.11%	1.000	182349	1.220	0	23239
neos-2978193-inde	0.50%	551173	0.50%	1.000	549249	0.997	0	0
	0.13%	582870	0.13%	1.000	573707	0.984	0	0
	0.50%	547662	0.50%	1.000	548119	1.001	0	0
neos-2987310-joes	17.53	1	17.49	0.998	1	1.000	0	0
	15.20	1	15.31	1.007	1	1.000	0	0
	13.92	1	13.67	0.982	1	1.000	0	0
neos-3004026-krka	53.34	2711	53.06	0.995	2711	1.000	0	0
	62.15	3485	62.47	1.005	3485	1.000	0	0
	46.66	1764	46.28	0.992	1764	1.000	0	0
neos-3024952-loue	4655.80	383076	4646.86	0.998	383076	1.000	0	0
	0.07%	689174	0.07%	1.000	688312	0.999	0	7592
	0.04%	1114735	0.04%	1.000	1114650	1.000	0	0
neos-3046615-murg	169.81%	6945244	169.81%	1.000	6971706	1.004	0	0
	166.18%	6350455	166.11%	1.000	6364063	1.002	0	0
	163.78%	7585476	163.66%	1.000	7613539	1.004	0	0
neos-3083819-nubu	10.59	750	12.72	*1.201*	2020	*2.693*	0	587
	11.06	914	12.37	*1.118*	1578	*1.726*	0	929
	17.29	2598	20.79	*1.202*	3812	*1.467*	0	1470
neos-3216931-puriri	102.17%	8202	116.41%	1.000	5546	0.676	0	908
	127.35%	9370	5.50%	1.000	9705	1.036	2	1889
	146.80%	4854	147.13%	1.000	4790	0.987	0	515
neos-3381206-awhea	1.18	1	1.18	1.000	1	1.000	0	0
	1.23	1	1.21	0.984	1	1.000	0	0
	1.21	1	1.20	0.992	1	1.000	0	0
neos-3402294-bobin	2927.48	23532	4386.37	*1.498*	40294	*1.712*	0	2407
	1177.76	7141	618.95	**0.526**	3428	**0.480**	0	215

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
	2598.45	26596	1620.92	**0.624**	9242	**0.347**	0	556
neos-3402454-bohle	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-3555904-turama	18.01%	160	18.01%	1.000	145	0.906	0	22
	∞	18	∞	1.000	18	1.000	0	2
	18.01%	2288	18.01%	1.000	16797	7.341	7	2965
neos-3627168-kasai	0.27%	4524556	0.15%	1.000	4555684	1.007	1176	160196
	0.08%	4096583	0.09%	1.000	4132791	1.009	1704	10707
	0.29%	4799230	0.27%	1.000	5147129	1.072	203	143528
neos-3656078-kumeu	∞	32	∞	1.000	32	1.000	0	0
	∞	82	∞	1.000	82	1.000	0	0
	∞	122	∞	1.000	122	1.000	0	0
neos-3754480-nidda	∞	19644660	∞	1.000	20000763	1.018	178916	52749
	∞	17700365	∞	1.000	18439214	1.042	111935	108610
	∞	19361020	∞	1.000	19108471	0.987	111385	87787
neos-3988577-wolgan	∞	309	∞	1.000	312	1.010	0	0
	∞	179	∞	1.000	179	1.000	0	0
	∞	439	∞	1.000	439	1.000	0	0
neos-4300652-rahue	482.22%	1381	431.97%	1.000	1365	0.988	0	639
	825.63%	1274	809.48%	1.000	1213	0.952	0	488
	292.94%	2406	316.83%	1.000	2127	0.884	0	723
neos-4338804-snowy	1.66%	4826235	1.66%	1.000	4875741	1.010	0	0
	0.82%	6661157	0.82%	1.000	6738902	1.012	0	0
	1.66%	5118687	1.66%	1.000	5067404	0.990	0	0
neos-4387871-tavua	13.49%	106621	11.39%	1.000	118375	1.110	0	7096
	10.75%	124065	14.13%	1.000	116171	0.936	0	8132
	13.96%	113215	18.66%	1.000	96695	0.854	0	7109
neos-4413714-turia	297.41	2	299.23	1.006	2	1.000	0	1
	403.92	2	404.80	1.002	2	1.000	0	1
	272.63	3	277.10	1.016	2	**0.667**	0	1
neos-4532248-waihi	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-4647030-tutaki	0.01%	24433	0.01%	1.000	24413	0.999	0	0
	0.01%	22711	0.01%	1.000	22893	1.008	0	0
	0.01%	26981	0.01%	1.000	27292	1.012	0	0
neos-4722843-widden	2662.61	11357	2651.33	0.996	11357	1.000	0	0
	1031.93	3416	1033.65	1.002	3376	0.988	16	0
	1707.07	7919	1714.52	1.004	7919	1.000	0	0
neos-4738912-atrato	1811.58	189048	813.40	**0.449**	61981	**0.328**	0	23163
	3350.87	293417	3808.90	*1.137*	324992	*1.108*	0	57398
	744.51	98248	914.39	*1.228*	95736	0.974	0	17171
neos-4763324-toguru	19.99%	8572	46.04%	1.000	8436	0.984	0	3555
	7.38%	14545	45.08%	1.000	14962	1.029	0	4939
	16.27%	15033	48.94%	1.000	7145	0.475	0	2598
neos-4954672-berkel	8.57%	952460	8.48%	1.000	1019990	1.071	2075	113794
	8.42%	897757	8.71%	1.000	819107	0.912	2681	80306
	7.87%	845279	8.00%	1.000	891993	1.055	2516	64177
neos-5049753-cuanza	∞	52	∞	1.000	52	1.000	0	0
	15.39%	14	15.39%	1.000	14	1.000	0	0
	15.20%	12	15.20%	1.000	12	1.000	0	0
neos-5052403-cygnet	1.60%	113	1.60%	1.000	113	1.000	0	6
	1.38%	1	1.38%	1.000	1	1.000	0	0
	1.19%	63	1.19%	1.000	63	1.000	0	9
neos-5093327-huahum	10.70%	50333	10.32%	1.000	49854	0.990	1300	0

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
	11.49%	50392	10.43%	1.000	52521	1.042	1173	0
	8.45%	56530	12.17%	1.000	48532	0.859	1077	0
neos-5104907-jarama	∞	8	∞	1.000	8	1.000	0	0
	∞	9	∞	1.000	9	1.000	0	0
	∞	4	∞	1.000	4	1.000	0	0
neos-5107597-kakapo	2135.00	560533	2144.47	1.004	560533	1.000	10	0
	1717.55	472676	1725.41	1.005	472393	0.999	31	0
	3237.82	1073257	5927.88	*1.831*	1725439	*1.608*	108	0
neos-5114902-kasavu	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
neos-5188808-nattai	1249.67	12145	1251.29	1.001	12145	1.000	0	0
	1288.24	13554	1292.07	1.003	13554	1.000	0	0
	1377.84	12548	1380.62	1.002	12548	1.000	0	0
neos-5195221-niemur	2728.17	53512	2813.87	1.031	47466	**0.887**	67	0
	2892.34	24415	2911.85	1.007	25010	1.024	36	0
	2857.51	31131	2890.78	1.012	33779	*1.085*	30	0
neos-631710	14.21%	2	14.21%	1.000	2	1.000	0	0
	8.90%	4	8.90%	1.000	4	1.000	0	0
	14.21%	3	14.21%	1.000	3	1.000	0	0
neos-662469	0.01%	58801	0.01%	1.000	59651	1.014	0	14409
	0.05%	63742	0.00%	1.000	50627	0.794	0	10313
	0.06%	61333	0.01%	1.000	56995	0.929	0	13271
neos-787933	1.39	1	1.37	0.986	1	1.000	0	0
	1.37	1	1.39	1.015	1	1.000	0	0
	1.35	1	1.41	1.044	1	1.000	0	0
neos-827175	6.14	1	6.10	0.993	1	1.000	0	0
	8.19	1	8.21	1.002	1	1.000	0	0
	10.24	1	10.23	0.999	1	1.000	0	0
neos-848589	32.15%	256	32.15%	1.000	256	1.000	2	0
	42.57%	153	42.95%	1.000	148	0.967	1	0
	46.27%	106	46.27%	1.000	106	1.000	0	0
neos-860300	17.23	2	17.27	1.002	2	1.000	0	0
	13.32	2	13.35	1.002	2	1.000	0	0
	23.14	3	23.18	1.002	3	1.000	0	0
neos-873061	9.28%	157	9.28%	1.000	155	0.987	0	17
	15.19%	141	7.72%	1.000	148	1.050	0	5
	8.12%	168	8.12%	1.000	168	1.000	0	6
neos-911970	0.76%	1608307	1.05%	1.000	1400854	0.871	0	62647
	2.98%	709744	2.49%	1.000	1814127	2.556	0	127461
	0.06%	8197877	0.06%	1.000	11460910	1.398	0	204690
neos-933966	3653.20	466	1374.28	**0.376**	138	**0.296**	0	12
	0.31%	2765	848.27	**0.118**	38	**0.014**	0	12
	2099.25	215	2180.73	1.039	283	*1.316*	0	26
neos-950242	100.00%	9329	100.00%	1.000	9288	0.996	0	0
	100.00%	8438	100.00%	1.000	8446	1.001	0	0
	100.00%	15646	100.00%	1.000	15629	0.999	0	0
neos-957323	81.84	7	86.06	*1.052*	2	**0.286**	0	4
	130.66	12	110.59	**0.846**	5	**0.417**	0	32
	91.28	1	80.10	**0.878**	2	*2.000*	0	5
neos-960392	879.61	15	881.09	1.002	15	1.000	0	0
	1447.01	102	1439.63	0.995	102	1.000	0	0
	1366.35	403	1363.87	0.998	403	1.000	0	1
neos17	16.19	12038	25.95	*1.603*	22460	*1.866*	0	2737
	9.91	6153	9.39	**0.948**	5644	**0.917**	0	350
	10.19	6745	9.84	0.966	6376	**0.945**	0	616

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
neos5	1008.28	3292114	1007.54	0.999	3292114	1.000	0	0
	1234.92	4202380	1234.24	0.999	4202380	1.000	0	0
	1187.61	4100005	1183.51	0.997	4100005	1.000	0	0
neos859080	0.53	792	0.50	**0.943**	792	1.000	0	0
	0.57	655	0.54	**0.947**	655	1.000	0	25
	0.54	565	0.55	1.019	565	1.000	0	0
neos8	1.94	1	1.95	1.005	1	1.000	0	0
	1.81	1	1.89	1.044	1	1.000	0	0
	1.84	1	1.83	0.995	1	1.000	0	0
net12	1841.31	1211	1842.42	1.001	1211	1.000	0	0
	1625.53	1816	1631.28	1.004	1816	1.000	0	0
	1563.27	1695	1561.43	0.999	1695	1.000	0	0
netdiversion	843.61	43	848.00	1.005	43	1.000	0	0
	2360.01	88	2364.82	1.002	88	1.000	0	0
	1086.34	27	1087.12	1.001	27	1.000	0	0
nexp-150-20-8-5	5607.49	7209	3539.59	**0.631**	5786	**0.803**	0	14901
	3991.89	9681	3635.13	**0.911**	7166	**0.740**	0	7301
	2066.62	3123	0.83%	3.484	13054	4.180	0	5623
ns1116954	∞	30	∞	1.000	32	1.067	0	0
	∞	57	∞	1.000	57	1.000	0	0
	∞	76	∞	1.000	75	0.987	0	0
ns1208400	300.18	1187	419.49	*1.397*	2004	*1.688*	0	204
	684.48	2737	683.06	0.998	2339	**0.855**	0	10
	1079.72	2315	1074.09	0.995	2315	1.000	0	25
ns1644855	7.37%	36	7.37%	1.000	36	1.000	0	0
	7.37%	79	7.37%	1.000	79	1.000	0	0
	974.40	1	974.47	1.000	1	1.000	0	0
ns1760995	58.41%	1	58.41%	1.000	1	1.000	0	0
	71.46%	1	71.46%	1.000	1	1.000	0	0
	48.93%	1	48.93%	1.000	1	1.000	0	0
ns1830653	237.00	14947	287.45	*1.213*	14558	0.974	0	1345
	151.53	7206	134.33	**0.886**	7527	1.045	0	955
	158.50	8634	148.24	**0.935**	7267	**0.842**	0	1000
ns1952667	∞	52490	∞	1.000	52208	0.995	0	0
	1410.99	9508	1392.38	0.987	9508	1.000	0	3988
	966.39	4900	968.90	1.003	4900	1.000	0	0
nu25-pr12	5.40	53	5.36	0.993	53	1.000	0	78
	6.08	66	6.11	1.005	66	1.000	0	67
	6.05	16	6.05	1.000	16	1.000	0	39
nursesched-medium-hint03	1979.33%	1208	1657.78%	1.000	1100	0.911	0	37
	1056.82%	1254	3021.25%	1.000	2050	1.635	0	4
	666.65%	1304	1077.84%	1.000	1121	0.860	0	19
nursesched-sprint02	143.09	377	142.08	0.993	370	0.981	0	73
	85.66	409	85.18	0.994	409	1.000	0	22
	68.77	222	67.71	0.985	222	1.000	0	40
nw04	37.96	6	37.93	0.999	6	1.000	0	5
	31.58	5	31.39	0.994	5	1.000	0	4
	35.83	6	35.16	0.981	6	1.000	0	10
opm2-z10-s4	30.57%	781	24.70%	1.000	1000	1.280	0	15
	24.92%	791	27.76%	1.000	586	0.741	0	28
	26.91%	751	26.96%	1.000	1015	1.352	0	127
p200x1188c	3.55	2	3.53	0.994	2	1.000	0	0
	4.50	3	3.96	**0.880**	3	1.000	0	3
	3.59	2	3.62	1.008	2	1.000	0	0
peg-solitaire-a3	∞	3657	∞	1.000	5752	1.573	0	1618
	∞	3703	∞	1.000	3557	0.961	0	993

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
	∞	4176	∞	1.000	3969	0.950	0	1037
pg5_34	1174.65	148717	1173.22	0.999	148717	1.000	0	0
	1139.04	144543	1134.07	0.996	144543	1.000	0	0
	1087.84	121673	1085.15	0.998	121673	1.000	0	0
pg	101.75	2687	101.85	1.001	2687	1.000	0	0
	86.34	1372	86.23	0.999	1372	1.000	0	0
	108.14	2311	107.44	0.994	2311	1.000	0	0
physiciansched3-3	∞	415	∞	1.000	415	1.000	0	0
	∞	313	∞	1.000	313	1.000	0	0
	∞	361	∞	1.000	361	1.000	0	2
physiciansched6-2	124.94	377	124.81	0.999	377	1.000	0	3
	464.85	2804	462.02	0.994	2804	1.000	0	0
	44.74	1	44.74	1.000	1	1.000	0	0
piperout-08	805.46	130	797.03	0.990	130	1.000	0	0
	610.42	552	606.54	0.994	552	1.000	0	0
	919.29	596	923.85	1.005	596	1.000	0	0
piperout-27	140.91	2	140.11	0.994	2	1.000	0	0
	276.16	566	275.91	0.999	566	1.000	0	0
	331.58	72	332.32	1.002	72	1.000	0	0
pk1	107.22	301100	107.55	1.003	301100	1.000	0	0
	109.73	317026	109.16	0.995	317026	1.000	0	0
	111.84	328715	112.34	1.004	328715	1.000	0	0
proteindesign121hz512p9	9.60%	579	9.60%	1.000	591	1.021	0	10
	15.68%	459	7.94%	1.000	440	0.959	0	104
	26.02%	593	26.02%	1.000	593	1.000	2	1
proteindesign122trx11p8	1.95%	3	1.95%	1.000	3	1.000	1	38
	1.92%	2	1.91%	1.000	8	4.000	2	213
	1.93%	17	1.93%	1.000	17	1.000	0	128
qap10	92.05	3	87.99	0.956	3	1.000	0	8
	95.66	3	111.82	*1.169*	5	*1.667*	0	3
	172.24	14	197.87	*1.149*	15	*1.071*	0	3
radiationm18-12-05	12.99%	480152	12.99%	1.000	479812	0.999	1	0
	0.05%	749612	0.05%	1.000	750150	1.001	3	0
	1.89%	550712	1.89%	1.000	551080	1.001	4	0
radiationm40-10-02	67.02%	53842	67.02%	1.000	53316	0.990	0	0
	57.74%	26955	57.74%	1.000	27109	1.006	0	0
	22.69%	97004	22.69%	1.000	99008	1.021	0	0
rail01	2.40%	187	2.74%	1.000	200	1.070	0	24
	25.38%	210	25.21%	1.000	182	0.867	0	17
	7.37%	104	7.32%	1.000	183	1.760	0	28
rail02	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
rail507	157.23	623	156.67	0.996	623	1.000	0	91
	179.18	783	180.04	1.005	783	1.000	0	105
	195.62	769	193.43	0.989	771	1.003	0	175
ran14x18-disj-8	2223.47	684795	2109.62	**0.949**	656920	0.959	0	41179
	1761.00	648842	1785.31	1.014	564900	**0.871**	0	41046
	1620.85	536125	1694.59	1.045	593570	*1.107*	0	39520
rd-rplusc-21	≥ 10000%	519165	≥ 10000%	1.000	484631	0.933	4	492
	≥ 10000%	676605	≥ 10000%	1.000	737139	1.089	4	25
	≥ 10000%	570746	≥ 10000%	1.000	763715	1.338	9	176
reblock115	0.15%	1086376	4390.48	**0.610**	704168	**0.648**	0	40664
	0.16%	1076715	6605.46	**0.917**	882785	**0.820**	0	53241
	0.06%	823999	5894.68	**0.819**	832788	1.011	0	52934
rmatr100-p10	166.19	809	166.48	1.002	809	1.000	0	0

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
	162.12	822	162.84	1.004	822	1.000	0	0
	160.95	827	160.62	0.998	827	1.000	0	0
rmatr200-p5	22.40%	423	22.40%	1.000	421	0.995	0	0
	19.56%	422	19.56%	1.000	423	1.002	0	0
	21.08%	402	21.08%	1.000	403	1.002	0	0
rocI-4-11	638.68	12970	638.21	0.999	12970	1.000	0	0
	1001.90	17602	1001.80	1.000	17602	1.000	0	0
	498.05	9550	498.07	1.000	9550	1.000	0	0
rocII-5-11	109.27%	3334	108.52%	1.000	3399	1.019	0	126
	108.98%	2853	109.87%	1.000	2764	0.969	0	118
	109.29%	2598	109.11%	1.000	2522	0.971	0	94
rococoB10-011000	13.92%	144924	13.71%	1.000	151103	1.043	0	5331
	15.37%	143892	15.09%	1.000	143253	0.996	0	7762
	13.34%	137107	12.80%	1.000	153839	1.122	0	6808
rococoC10-001000	1600.78	148511	765.76	**0.478**	53303	**0.359**	0	10771
	764.66	44285	851.99	*1.114*	63090	*1.425*	0	15639
	940.72	59267	1626.91	*1.729*	162527	*2.742*	0	36515
roi2alpha3n4	1763.64	15468	1424.80	**0.808**	12529	**0.810**	0	6122
	1888.36	15975	1940.46	1.028	17446	*1.092*	0	8516
	1456.75	13317	1486.54	1.020	13303	0.999	0	6848
roi5alpha10n8	35.44%	5821	35.37%	1.000	5989	1.029	0	4924
	32.93%	6871	40.36%	1.000	6346	0.924	0	4299
	32.14%	6691	32.14%	1.000	6789	1.015	0	5671
roll3000	36.10	2315	36.86	1.021	1986	**0.858**	0	714
	43.24	2623	38.91	**0.900**	2149	**0.819**	0	429
	35.13	1254	60.26	*1.715*	3736	*2.979*	0	1178
s100	5.53%	20	5.53%	1.000	20	1.000	0	0
	29.84%	17	29.84%	1.000	17	1.000	0	0
	1.06%	22	1.06%	1.000	22	1.000	0	127
s250r10	0.25%	23159	0.28%	1.000	22897	0.989	0	4109
	0.16%	53768	6366.45	**0.884**	45426	**0.845**	0	22032
	0.19%	34836	0.23%	1.000	31811	0.913	0	12717
satellites2-40	∞	19	∞	1.000	19	1.000	0	0
	∞	6	∞	1.000	4	0.667	0	0
	70.59%	33	70.59%	1.000	33	1.000	0	0
satellites2-60-fs	∞	33	∞	1.000	33	1.000	0	0
	∞	122	∞	1.000	137	1.123	0	10
	∞	28	∞	1.000	28	1.000	0	0
savsched1	∞	1	∞	1.000	1	1.000	0	1
	∞	1	∞	1.000	1	1.000	0	1
	∞	1	∞	1.000	1	1.000	0	1
sct2	0.03%	848166	0.03%	1.000	600226	0.708	0	26147
	0.06%	693585	0.05%	1.000	659682	0.951	0	20668
	0.03%	1040105	0.03%	1.000	994927	0.957	0	20050
seymour1	90.36	1627	90.45	1.001	1627	1.000	0	0
	67.69	1466	67.90	1.003	1466	1.000	0	0
	71.78	1822	72.05	1.004	1822	1.000	0	0
seymour	0.73%	235347	0.66%	1.000	242500	1.030	0	5789
	0.63%	213496	0.68%	1.000	222209	1.041	0	6059
	0.68%	240665	0.74%	1.000	225373	0.936	0	6259
sing326	0.17%	6850	0.15%	1.000	11755	1.716	0	523
	0.15%	7092	0.17%	1.000	8196	1.156	0	432
	0.12%	13196	0.32%	1.000	7997	0.606	0	853
sing44	0.41%	5591	0.45%	1.000	5531	0.989	0	249
	0.23%	7062	0.19%	1.000	7349	1.041	0	345
	0.17%	3892	0.27%	1.000	2267	0.582	0	292

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
snp-02-004-104	0.00%	14573	0.00%	1.000	14561	0.999	0	0
	0.00%	18040	0.00%	1.000	18040	1.000	2	0
	0.00%	19695	0.00%	1.000	19680	0.999	8	0
sorrell3	35.13%	41274	43.81%	1.000	41208	0.998	0	3480
	45.00%	39264	35.59%	1.000	39514	1.006	0	2619
	18.16%	14782	19.11%	1.000	8801	0.595	0	4288
sp150x300d	4.05	3472	3.96	0.978	3472	1.000	0	478
	3.18	2569	3.12	0.981	2569	1.000	0	374
	1.30	848	1.29	0.992	848	1.000	0	148
sp97ar	1.25%	24002	0.98%	1.000	15747	0.656	0	1436
	1.04%	25138	1.02%	1.000	22961	0.913	0	1912
	1.37%	22524	1.53%	1.000	24828	1.102	0	3564
sp98ar	0.70%	48051	1.43%	1.000	71746	1.493	0	4469
	0.50%	55454	0.48%	1.000	67060	1.209	0	5933
	0.73%	48778	0.98%	1.000	71271	1.461	0	14342
splice1k1	309.21%	411	309.20%	1.000	513	1.248	0	130
	376.20%	503	376.10%	1.000	594	1.181	0	181
	358.74%	1033	358.74%	1.000	834	0.807	0	73
square41	109.98%	30	109.98%	1.000	30	1.000	0	10
	92.32%	5	89.32%	1.000	37	7.400	0	4
	79.78%	11	92.32%	1.000	28	2.545	0	1
square47	231.21%	4	231.21%	1.000	4	1.000	0	0
	117.00%	13	117.00%	1.000	13	1.000	0	1
	231.21%	3	231.21%	1.000	1	0.333	0	1
supportcase10	803.51%	1	803.51%	1.000	1	1.000	0	0
	989.07%	1	989.07%	1.000	1	1.000	0	0
	1054.36%	1	1054.36%	1.000	1	1.000	0	0
supportcase12	1.31%	1454	1.31%	1.000	1463	1.006	0	0
	1.35%	2280	1.35%	1.000	2297	1.007	0	0
	1.30%	1522	1.30%	1.000	1505	0.989	0	0
supportcase18	3.84%	394624	3.84%	1.000	419350	1.063	0	12210
	5.96%	226660	5.96%	1.000	237591	1.048	0	11386
	3.84%	245639	3.84%	1.000	198815	0.809	0	18486
supportcase19	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	0	0
supportcase22	∞	51	∞	1.000	51	1.000	0	1
	∞	18	∞	1.000	18	1.000	0	0
	∞	66	∞	1.000	66	1.000	0	0
supportcase26	8.94%	8140773	8.94%	1.000	8135621	0.999	4	0
	5261.03	6761735	5238.22	0.996	6761735	1.000	0	0
	4507.34	5497025	4487.28	0.996	5497025	1.000	0	0
supportcase33	1488.12	10781	1598.38	*1.074*	12756	*1.183*	0	5003
	3927.65	20793	1600.98	**0.408**	7176	**0.345**	0	4139
	2636.30	22200	682.16	**0.259**	3786	**0.171**	0	2673
supportcase40	787.96	6335	786.50	0.998	6335	1.000	0	0
	950.06	7991	946.94	0.997	7991	1.000	0	0
	803.31	6970	797.74	0.993	6970	1.000	0	0
supportcase42	0.36%	389477	0.38%	1.000	305571	0.785	16	0
	0.12%	487868	0.10%	1.000	380155	0.779	15	0
	0.35%	466458	0.35%	1.000	467610	1.002	4	0
supportcase6	10.15%	14606	9.13%	1.000	18980	1.299	0	5977
	10.04%	16253	8.41%	1.000	17726	1.091	0	5426
	9.14%	18145	9.72%	1.000	17709	0.976	0	3696
supportcase7	182.77	59	179.98	0.985	59	1.000	0	0
	195.10	45	193.62	0.992	45	1.000	0	0

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Table A.6: Detailed computational results on MIPLIB 2017 benchmark with and without filtering dual proofs.

	filtering disabled		combined					
Instance	T	N	T	T_Q	N	N_Q	Fn	Fl
	211.44	32	210.25	0.994	32	1.000	0	0
swath1	18.88	225	21.09	*1.117*	281	*1.249*	0	458
	15.98	175	17.34	*1.085*	245	*1.400*	0	384
	16.12	190	19.82	*1.230*	292	*1.537*	0	375
swath3	285.63	40400	226.20	**0.792**	28316	**0.701**	0	2847
	215.30	23312	182.91	**0.850**	21837	**0.937**	0	2411
	335.65	53934	427.45	*1.273*	74192	*1.376*	0	5631
tbfp-network	2493.68	323	2356.81	**0.945**	574	*1.777*	0	235
	1687.55	71	1683.80	0.998	71	1.000	0	18
	1092.72	99	1088.57	0.996	99	1.000	0	42
thor50dday	23.30%	95	23.30%	1.000	95	1.000	0	7
	21.49%	13	21.49%	1.000	12	0.923	0	1
	14.80%	36	14.80%	1.000	34	0.944	0	0
timtab1	69.88	56513	73.73	*1.055*	64175	*1.136*	0	3137
	70.24	54392	67.90	0.967	51540	**0.948**	0	2251
	81.32	64759	70.92	**0.872**	55054	**0.850**	0	3270
tr12-30	608.69	423661	606.97	0.997	423661	1.000	0	0
	647.41	475420	650.32	1.004	475420	1.000	0	0
	399.86	211580	397.52	0.994	213946	1.011	3	29
traininstance2	$\geq$ 10000%	57909	∞	1.000	67099	1.159	0	2934
	∞	57559	∞	1.000	52063	0.905	0	4459
	∞	56089	6286.13%	1.000	73138	1.304	1	2682
traininstance6	656.91%	429240	634.16%	1.000	456248	1.063	0	41885
	596.81%	466043	626.92%	1.000	347529	0.746	0	24445
	685.56%	369433	520.12%	1.000	454368	1.230	0	39689
trento1	0.08%	51522	0.07%	1.000	57766	1.121	0	17518
	0.07%	67101	0.10%	1.000	51033	0.761	0	14570
	2.86%	33340	1.67%	1.000	35013	1.050	0	4333
triptim1	1112.15	8	1099.43	0.989	8	1.000	0	0
	749.66	7	747.73	0.997	7	1.000	0	0
	1059.75	8	1065.09	1.005	8	1.000	0	0
uccase12	0.00%	77081	0.00%	1.000	77800	1.009	0	0
	0.00%	91920	0.00%	1.000	91468	0.995	0	0
	0.00%	97971	0.00%	1.000	98605	1.006	0	0
uccase9	1.98%	608	1.98%	1.000	498	0.819	0	52
	1.16%	883	1.48%	1.000	1166	1.320	0	35
	2.84%	512	2.82%	1.000	550	1.074	0	66
uct-subprob	1107.60	39010	1102.62	0.996	44339	*1.137*	0	3576
	2167.46	85998	1631.60	**0.753**	59559	**0.693**	0	5112
	2386.63	83769	2506.36	*1.050*	95674	*1.142*	0	6420
unitcal_7	272.88	89	272.59	0.999	89	1.000	5	0
	297.97	180	298.12	1.001	180	1.000	0	0
	384.79	436	387.18	1.006	436	1.000	1	0
var-smallemery-m6j6	0.89%	629156	0.93%	1.000	568323	0.903	0	38516
	0.90%	648593	0.87%	1.000	656232	1.012	0	55395
	6320.27	700461	6729.45	*1.065*	683202	0.975	0	39067
wachplan	2476.62	219408	2340.84	**0.945**	219938	1.002	0	32589
	3179.70	286834	3419.67	*1.075*	302179	*1.053*	0	54422
	2439.36	191025	2343.95	0.961	198054	1.037	0	31992

Appendix B

Conflict-Free Learning

This chapter presents detailed computational results of the experiments discussed in Chapter 4.

Table B.1 illustrates the overall impact of solution learning (`sollearning`), conflict-free learning (`conffree`), and using both approach at the same time (`combined`). Baseline is SCIP without any of these techniques (`default`). The table shows

- The overall number of analyzed subproblems (#**CFC**)
- The overall number of conflict-free dual proofs added to the solving process (#**CFA**)

Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	default		sollearning				confree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
30n20b8	68.13	5	68.18	1.001	5	1.000	68.24	1.002	5	1.000	3	0	67.60	0.992	5	1.000	3	0
	331.37	301	330.89	0.999	301	1.000	250.64	**0.757**	167	**0.666**	132	19	250.32	**0.756**	167	**0.666**	132	19
	97.59	2	97.63	1.000	2	1.000	97.47	0.999	2	1.000	5	0	98.00	1.004	2	1.000	5	0
50v-10	1.41%	993.51K	1.41%	1.000	997.41K	1.004	1.42%	1.000	970.43K	0.977	1.42M	0	1.42%	1.000	968.20K	0.975	1.42M	0
	1.54%	936.59K	1.54%	1.000	937.46K	1.001	1.56%	1.000	910.87K	0.973	1.33M	0	1.55%	1.000	914.79K	0.977	1.34M	0
	1.48%	886.11K	1.48%	1.000	886.67K	1.001	1.50%	1.000	859.43K	0.970	1.29M	0	1.50%	1.000	857.33K	0.968	1.29M	0
CMS750_4	520.89	14.71K	522.18	1.002	14.71K	1.000	529.70	1.017	14.71K	1.000	14.95K	0	529.04	1.016	14.71K	1.000	14.95K	0
	533.86	20.85K	530.88	0.994	20.85K	1.000	545.54	1.022	20.85K	1.000	20.45K	0	544.87	1.021	20.85K	1.000	20.45K	0
	1535.56	16.79K	1541.49	1.004	16.79K	1.000	1546.30	1.007	16.79K	1.000	16.77K	0	1548.96	1.009	16.79K	1.000	16.77K	0
academictimetablesmall	3.36	0	3.46	1.023	0	1.000	3.31	0.989	0	1.000	0	0	3.38	1.005	0	1.000	0	0
	3.08	0	3.03	0.988	0	1.000	3.10	1.005	0	1.000	0	0	3.07	0.998	0	1.000	0	0
	3.40	0	3.35	0.989	0	1.000	3.42	1.005	0	1.000	0	0	3.45	1.011	0	1.000	0	0
air05	34.28	501	34.58	1.009	501	1.000	34.67	1.011	501	1.000	426	0	34.52	1.007	501	1.000	426	0
	36.53	654	37.76	1.033	745	*1.121*	36.90	1.010	654	1.000	515	0	38.55	*1.054*	745	*1.121*	610	0
	26.29	229	26.75	1.017	235	1.018	26.39	1.004	229	1.000	191	0	26.69	1.015	235	1.018	202	0
app1-1	3.79	2	3.86	1.015	2	1.000	3.84	1.010	2	1.000	53	0	3.82	1.006	2	1.000	53	0
	4.22	6	4.16	0.989	6	1.000	4.21	0.998	6	1.000	68	0	4.18	0.992	6	1.000	68	0
	3.14	2	3.09	0.988	2	1.000	3.11	0.993	2	1.000	42	0	3.16	1.005	2	1.000	42	0
app1-2	187.01%	28.57K	187.01%	1.000	28.57K	1.000	187.01%	1.000	28.56K	1.000	19.62K	0	187.01%	1.000	28.56K	1.000	19.62K	0
	572.22	661	574.04	1.003	661	1.000	575.47	1.006	661	1.000	472	0	573.84	1.003	661	1.000	472	0
	720.71	978	722.01	1.002	978	1.000	722.24	1.002	978	1.000	649	0	722.63	1.003	978	1.000	649	0
assign1-5-8	4276.38	7.46M	4278.49	1.000	7.46M	1.000	3993.74	**0.934**	6.65M	**0.891**	4.37M	1.84K	3966.97	**0.928**	6.65M	**0.891**	4.37M	1.84K
	5861.66	9.89M	5871.08	1.002	9.89M	1.000	2982.52	**0.509**	5.02M	**0.507**	3.21M	1.12K	2960.88	**0.505**	5.02M	**0.507**	3.21M	1.12K
	2881.84	5.26M	2883.61	1.001	5.26M	1.000	3170.79	*1.100*	5.80M	*1.103*	3.81M	1.46K	3164.61	*1.098*	5.80M	*1.103*	3.81M	1.46K
atlanta-ip	5.29%	19.39K	5.30%	1.000	19.18K	0.989	5.31%	1.000	19.16K	0.988	19.22K	0	5.31%	1.000	19.07K	0.984	19.13K	0
	9.80%	19.35K	9.80%	1.000	19.34K	0.999	9.81%	1.000	19.15K	0.989	18.94K	0	9.81%	1.000	19.13K	0.989	18.93K	0
	9.84%	12.37K	9.85%	1.000	12.36K	0.999	9.85%	1.000	12.26K	0.991	12.15K	0	9.85%	1.000	12.26K	0.991	12.15K	0
b1c1s1	13.96%	54.38K	13.97%	1.000	54.13K	0.995	14.32%	1.000	53.89K	0.991	53.60K	4	14.32%	1.000	53.87K	0.991	53.58K	4
	12.30%	46.66K	12.30%	1.000	46.74K	1.002	12.31%	1.000	47.97K	1.028	47.48K	6	12.32%	1.000	47.41K	1.016	46.92K	6
	12.51%	48.65K	12.52%	1.000	48.61K	0.999	12.62%	1.000	49.59K	1.019	51.76K	6	12.62%	1.000	49.67K	1.021	51.84K	6
bab2	1.41%	1.58K	1.41%	1.000	1.58K	0.999	1.41%	1.000	1.57K	0.999	1.94K	0	1.41%	1.000	1.57K	0.999	1.94K	0
	1.09%	6.57K	1.08%	1.000	6.66K	1.015	1.09%	1.000	6.54K	0.995	6.57K	0	1.09%	1.000	6.52K	0.994	6.56K	0
	0.65%	3.75K	0.65%	1.000	3.77K	1.004	0.65%	1.000	3.60K	0.962	5.14K	0	0.65%	1.000	3.64K	0.972	5.20K	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
bab6	1.19%	8.12K	1.19%	1.000	8.17K	1.006	1.19%	1.000	7.75K	0.956	11.04K	0	1.19%	1.000	7.76K	0.957	11.05K	0
	1.74%	2.54K	1.74%	1.000	2.54K	1.000	1.77%	1.000	3.36K	1.314	5.12K	0	1.40%	1.000	3.43K	1.339	5.23K	0
	2.34%	6.50K	2.34%	1.000	6.32K	0.972	2.34%	1.000	6.24K	0.960	7.80K	0	2.34%	1.000	6.32K	0.972	7.92K	0
beasleyC3	20.43	2	20.50	1.003	2	1.000	20.49	1.003	2	1.000	3	0	20.53	1.005	2	1.000	3	0
	28.35	2	28.30	0.998	2	1.000	28.56	1.007	2	1.000	8	0	28.48	1.004	2	1.000	8	0
	60.96	779	61.18	1.004	779	1.000	66.73	*1.093*	959	*1.205*	1.38K	1.25K	66.66	*1.092*	959	*1.205*	1.38K	1.25K
binkar10_1	35.91	3.21K	35.94	1.001	3.21K	1.000	36.33	1.011	3.21K	1.000	3.39K	0	36.41	1.014	3.21K	1.000	3.39K	0
	27.57	2.63K	27.64	1.002	2.63K	1.000	28.00	1.015	2.63K	1.000	2.75K	0	27.93	1.013	2.63K	1.000	2.75K	0
	32.31	3.00K	32.29	0.999	3.00K	1.000	32.84	1.016	3.00K	1.000	3.14K	0	32.59	1.008	3.00K	1.000	3.14K	0
blp-ar98	0.27%	219.23K	0.27%	1.000	218.36K	0.996	0.28%	1.000	207.82K	0.948	154.58K	0	0.28%	1.000	206.19K	0.941	153.44K	0
	0.25%	222.35K	0.25%	1.000	226.34K	1.018	0.25%	1.000	212.55K	0.956	159.31K	0	0.25%	1.000	211.13K	0.950	158.33K	0
	0.20%	222.83K	0.20%	1.000	224.09K	1.006	0.21%	1.000	212.96K	0.956	156.88K	0	0.21%	1.000	212.97K	0.956	156.88K	0
blp-ic98	1.74%	293.76K	1.74%	1.000	294.57K	1.003	1.88%	1.000	274.48K	0.934	177.87K	0	1.88%	1.000	275.59K	0.938	178.56K	0
	0.62%	310.82K	0.62%	1.000	310.26K	0.998	0.64%	1.000	288.56K	0.928	188.03K	0	0.64%	1.000	290.89K	0.936	189.43K	0
	0.83%	266.88K	0.83%	1.000	269.24K	1.009	0.93%	1.000	252.11K	0.945	169.09K	0	0.93%	1.000	251.06K	0.941	168.42K	0
bnatt400	289.62	8.44K	289.39	0.999	8.43K	0.999	290.98	1.005	8.44K	1.000	5.44K	0	290.37	1.003	8.43K	0.999	5.43K	0
	296.83	6.56K	298.97	1.007	6.60K	1.005	297.96	1.004	6.56K	1.000	4.30K	0	299.24	1.008	6.60K	1.005	4.32K	0
	221.59	7.51K	225.79	1.019	7.52K	1.001	223.67	1.009	7.51K	1.000	4.82K	0	229.29	1.035	7.52K	1.001	4.82K	0
bnatt500	704.91	24.40K	703.15	0.998	24.40K	1.000	704.94	1.000	24.40K	1.000	15.58K	0	707.92	1.004	24.40K	1.000	15.58K	0
	556.21	21.25K	556.89	1.001	21.25K	1.000	560.61	1.008	21.25K	1.000	13.43K	0	559.24	1.005	21.25K	1.000	13.43K	0
	947.82	32.11K	946.03	0.998	32.11K	1.000	948.39	1.001	32.11K	1.000	20.33K	0	952.09	1.005	32.11K	1.000	20.33K	0
bppc4-08	1.92%	702.34K	1.92%	1.000	704.43K	1.003	1.92%	1.000	701.37K	0.999	355.24K	0	1.92%	1.000	703.22K	1.001	356.16K	0
	1.92%	659.32K	1.92%	1.000	659.82K	1.001	1.92%	1.000	657.88K	0.998	341.43K	0	1.92%	1.000	659.73K	1.001	342.37K	0
	1.92%	713.92K	1.92%	1.000	716.60K	1.004	1.92%	1.000	715.17K	1.002	370.80K	0	1.92%	1.000	715.32K	1.002	370.68K	0
brazil3	6169.71	1.71K	6369.63	1.032	1.79K	1.044	6187.88	1.003	1.71K	1.000	1.58K	0	6402.18	1.038	1.79K	1.044	1.60K	0
	5308.34	2.11K	5297.82	0.998	2.11K	1.000	5315.89	1.001	2.11K	1.000	2.87K	0	5307.69	1.000	2.11K	1.000	2.87K	0
	243.75%	1.72K	243.75%	1.000	1.72K	1.001	243.75%	1.000	1.72K	0.998	1.74K	0	243.75%	1.000	1.72K	1.000	1.74K	0
buildingenergy	0.12%	21	0.12%	1.000	21	1.000	0.12%	1.000	60	1.322	133	120	0.12%	1.000	60	1.322	132	119
	5500.63	7	5411.49	0.984	7	1.000	5464.62	0.993	7	1.000	61	0	5486.96	0.998	7	1.000	61	0
	0.15%	57	0.15%	1.000	56	0.994	0.15%	1.000	70	1.083	75	59	0.15%	1.000	70	1.083	75	59
cbs-cta	271.74	201	272.56	1.003	201	1.000	271.69	1.000	201	1.000	211	0	272.20	1.002	201	1.000	211	0
	58.87	1	58.94	1.001	1	1.000	58.86	1.000	1	1.000	1	0	58.94	1.001	1	1.000	1	0
	4.77	1	4.76	0.998	1	1.000	4.77	1.000	1	1.000	1	0	4.74	0.995	1	1.000	1	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
chromaticindex1024-7	33.33%	3.75K	33.33%	1.000	3.78K	1.007	33.33%	1.000	3.73K	0.994	3.70K	0	33.33%	1.000	3.75K	0.999	3.72K	0
	33.33%	4.19K	33.33%	1.000	4.17K	0.995	33.33%	1.000	4.10K	0.977	4.01K	0	33.33%	1.000	4.08K	0.973	3.99K	0
	33.33%	3.28K	33.33%	1.000	3.29K	1.003	33.33%	1.000	3.25K	0.991	3.23K	0	33.33%	1.000	3.25K	0.990	3.23K	0
chromaticindex512-7	3965.14	11.97K	4002.29	1.009	11.97K	1.000	4046.09	1.020	11.97K	1.000	7.03K	0	4033.98	1.017	11.97K	1.000	7.03K	0
	883.71	327	881.97	0.998	327	1.000	882.62	0.999	327	1.000	196	0	886.60	1.003	327	1.000	196	0
	1224.07	2.67K	1222.70	0.999	2.67K	1.000	1235.22	1.009	2.67K	1.000	1.38K	0	1231.90	1.006	2.67K	1.000	1.38K	0
cmflsp50-24-8-8	3.28%	58.47K	3.28%	1.000	58.54K	1.001	3.29%	1.000	56.61K	0.968	62.52K	0	3.29%	1.000	56.74K	0.970	62.65K	0
	0.83%	78.70K	0.83%	1.000	78.60K	0.999	0.85%	1.000	76.74K	0.975	85.83K	0	0.85%	1.000	76.72K	0.975	85.81K	0
	5.41%	58.33K	5.42%	1.000	57.48K	0.985	6.81%	1.000	54.95K	0.942	49.55K	0	∞	1.000	54.57K	0.936	49.22K	0
co-100	5341.41	8.16K	5363.53	1.004	8.16K	1.000	5381.84	1.008	8.16K	1.000	8.67K	0	5312.33	0.995	8.16K	1.000	8.67K	0
	0.16%	24.02K	0.15%	1.000	24.17K	1.006	0.16%	1.000	23.99K	0.999	23.31K	0	0.16%	1.000	23.92K	0.996	23.20K	0
	3373.34	5.00K	3354.83	0.995	5.00K	1.000	3375.51	1.001	5.00K	1.000	5.14K	0	3362.04	0.997	5.00K	1.000	5.14K	0
cod105	461.21	571	461.30	1.000	571	1.000	461.14	1.000	571	1.000	377	0	460.79	0.999	571	1.000	377	0
	398.42	151	396.78	0.996	151	1.000	398.29	1.000	151	1.000	88	0	397.89	0.999	151	1.000	88	0
	294.42	35	295.33	1.003	35	1.000	296.42	1.007	35	1.000	32	0	295.49	1.004	35	1.000	32	0
comp07-2idx	800.00%	1.86K	783.33%	1.000	2.45K	1.298	800.00%	1.000	1.86K	0.999	1.90K	0	783.33%	1.000	2.44K	1.294	2.38K	0
	566.67%	1.92K	566.67%	1.000	1.93K	1.002	566.67%	1.000	1.93K	1.007	1.92K	0	566.67%	1.000	1.94K	1.007	1.92K	0
	966.67%	2.67K	616.67%	1.000	2.44K	0.919	966.67%	1.000	2.67K	1.000	2.64K	0	616.67%	1.000	2.45K	0.921	2.27K	0
comp21-2idx	214.01%	12.78K	213.61%	1.000	11.62K	0.910	214.01%	1.000	12.79K	1.001	12.13K	0	214.04%	1.000	11.46K	0.898	11.21K	0
	148.09%	9.85K	142.00%	1.000	9.93K	1.008	148.09%	1.000	9.82K	0.997	8.93K	0	142.00%	1.000	9.88K	1.003	9.35K	0
	184.55%	9.22K	180.10%	1.000	8.34K	0.905	177.18%	1.000	11.14K	1.206	9.09K	0	177.18%	1.000	11.11K	1.203	9.06K	0
cost266-UUE	3182.37	253.91K	3199.07	1.005	253.91K	1.000	3271.95	1.028	253.91K	1.000	240.60K	0	3279.13	1.030	253.91K	1.000	240.60K	0
	4917.07	362.94K	4884.44	0.993	362.94K	1.000	5003.46	1.018	362.94K	1.000	345.98K	0	5042.98	1.026	362.94K	1.000	345.98K	0
	2922.10	197.83K	2942.04	1.007	197.83K	1.000	3011.55	1.031	197.83K	1.000	189.62K	0	2999.10	1.026	197.83K	1.000	189.62K	0
cryptanalysiskb128n5obj14	∞	197	∞	1.000	197	1.000	∞	1.000	195	0.993	108	0	∞	1.000	195	0.993	108	0
	∞	120	∞	1.000	121	1.005	∞	1.000	121	1.005	68	0	∞	1.000	122	1.009	69	0
	∞	161	∞	1.000	159	0.992	∞	1.000	160	0.996	95	0	∞	1.000	162	1.004	95	0
cryptanalysiskb128n5obj16	∞	280	∞	1.000	279	0.997	∞	1.000	279	0.997	148	0	∞	1.000	279	0.997	148	0
	∞	75	∞	1.000	75	1.000	∞	1.000	73	0.989	44	0	∞	1.000	75	1.000	44	0
	∞	132	∞	1.000	132	1.000	∞	1.000	132	1.000	74	0	∞	1.000	132	1.000	74	0
csched007	2434.73	206.54K	2660.30	*1.093*	216.43K	1.048	2468.61	1.014	206.54K	1.000	270.09K	0	2712.83	*1.114*	216.43K	1.048	282.70K	0
	1616.12	143.11K	1748.92	*1.082*	151.32K	*1.057*	1638.38	1.014	143.11K	1.000	187.80K	0	1776.77	*1.099*	151.32K	*1.057*	201.36K	0
	2969.06	223.12K	2250.75	**0.758**	183.48K	**0.822**	3023.07	1.018	223.12K	1.000	292.68K	0	2276.95	**0.767**	183.48K	**0.822**	243.27K	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
csched008	699.62	69.17K	761.05	*1.088*	78.35K	*1.132*	701.15	1.002	69.17K	1.000	49.58K	0	763.95	*1.092*	78.35K	*1.132*	54.62K	0
	1080.88	102.25K	1082.95	1.002	102.25K	1.000	1085.08	1.004	102.25K	1.000	75.68K	0	1086.90	1.006	102.25K	1.000	75.68K	0
	520.13	51.90K	361.90	**0.696**	29.73K	**0.574**	522.12	1.004	51.90K	1.000	33.86K	0	362.18	**0.697**	29.73K	**0.574**	22.34K	0
cvs16r128-89	9.35%	66.16K	11.87%	1.000	59.50K	0.900	9.45%	1.000	39.34K	0.595	24.62K	23.51K	10.49%	1.000	43.71K	0.661	26.25K	25.33K
	14.09%	32.36K	13.92%	1.000	37.95K	1.172	12.87%	1.000	37.95K	1.172	24.14K	23.21K	12.96%	1.000	46.12K	1.424	28.89K	27.81K
	11.27%	98.42K	10.57%	1.000	55.17K	0.561	9.95%	1.000	42.43K	0.432	25.16K	24.25K	10.46%	1.000	38.57K	0.392	23.09K	22.31K
dano3_3	110.68	8	110.60	0.999	8	1.000	110.66	1.000	8	1.000	11	0	110.12	0.995	8	1.000	11	0
	92.36	12	92.37	1.000	12	1.000	92.47	1.001	12	1.000	18	0	92.55	1.002	12	1.000	18	0
	108.46	17	108.18	0.997	17	1.000	107.90	0.995	17	1.000	20	0	107.77	0.994	17	1.000	20	0
dano3_5	459.71	211	458.54	0.997	211	1.000	459.94	1.000	211	1.000	249	0	460.76	1.002	211	1.000	249	0
	407.28	276	405.94	0.997	276	1.000	405.28	0.995	276	1.000	362	0	405.50	0.996	276	1.000	362	0
	362.97	172	361.34	0.996	172	1.000	363.27	1.001	172	1.000	179	0	363.90	1.003	172	1.000	179	0
decomp2	16.86	1	16.97	1.006	1	1.000	16.85	0.999	1	1.000	1	0	16.87	1.001	1	1.000	1	0
	15.94	1	16.01	1.004	1	1.000	15.71	0.986	1	1.000	1	0	15.70	0.986	1	1.000	1	0
	12.03	1	12.03	1.000	1	1.000	12.05	1.002	1	1.000	1	0	11.99	0.997	1	1.000	1	0
drayage-100-23	8.93	6	8.97	1.004	6	1.000	8.96	1.003	6	1.000	9	0	8.86	0.993	6	1.000	9	0
	25.60	65	25.66	1.002	65	1.000	25.70	1.004	65	1.000	82	0	25.72	1.005	65	1.000	82	0
	9.37	109	9.44	1.007	109	1.000	9.47	1.010	109	1.000	109	0	9.53	1.015	109	1.000	109	0
drayage-25-23	0.07%	945.87K	0.07%	1.000	948.26K	1.003	0.07%	1.000	911.80K	0.964	486.20K	0	0.07%	1.000	910.56K	0.963	485.54K	0
	225.47	30.62K	226.07	1.003	30.62K	1.000	240.66	*1.067*	30.62K	1.000	17.60K	0	242.24	*1.074*	30.62K	1.000	17.60K	0
	138.29	17.52K	138.81	1.004	17.52K	1.000	145.83	*1.054*	17.52K	1.000	9.54K	0	146.06	*1.056*	17.52K	1.000	9.54K	0
dws008-01	49.26%	153.76K	49.16%	1.000	155.57K	1.012	49.66%	1.000	147.49K	0.959	214.95K	0	49.79%	1.000	146.40K	0.952	213.74K	0
	40.65%	155.51K	40.61%	1.000	156.38K	1.006	41.09%	1.000	150.38K	0.967	219.97K	0	41.09%	1.000	150.33K	0.967	219.91K	0
	38.12%	148.33K	38.00%	1.000	149.93K	1.011	38.58%	1.000	142.80K	0.963	203.16K	0	38.67%	1.000	142.01K	0.957	202.24K	0
eil33-2	76.31	715	76.02	0.996	715	1.000	77.93	1.021	715	1.000	2.72K	0	77.53	1.016	715	1.000	2.72K	0
	74.22	649	74.29	1.001	649	1.000	75.92	1.023	647	0.997	2.51K	18	76.22	1.027	647	0.997	2.51K	18
	75.43	625	75.86	1.006	625	1.000	77.39	1.026	625	1.000	2.77K	0	76.83	1.018	625	1.000	2.77K	0
eilA101-2	8.35%	13.31K	8.44%	1.000	13.04K	0.979	8.44%	1.000	11.27K	0.848	8.89K	0	8.44%	1.000	11.71K	0.880	9.21K	0
	19.68%	9.63K	19.68%	1.000	9.76K	1.013	19.75%	1.000	8.81K	0.916	6.91K	0	19.75%	1.000	8.74K	0.909	6.84K	0
	15.14%	10.58K	15.14%	1.000	10.79K	1.019	15.14%	1.000	10.08K	0.954	8.41K	0	15.14%	1.000	10.02K	0.948	8.34K	0
enlight_hard	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0	0	0.50	1.000	1	1.000	0	0
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0	0	0.50	1.000	1	1.000	0	0
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0	0	0.50	1.000	1	1.000	0	0

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Table B.1: Detailed computational results on Miplib 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				confree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
ex10	485.44	1	486.56	1.002	1	1.000	484.85	0.999	1	1.000	0	0	483.53	0.996	1	1.000	0	0
	559.76	1	560.77	1.002	1	1.000	560.44	1.001	1	1.000	0	0	560.40	1.001	1	1.000	0	0
	446.84	1	451.88	1.011	1	1.000	448.35	1.003	1	1.000	0	0	449.16	1.005	1	1.000	0	0
ex9	27.01	1	26.54	0.983	1	1.000	27.08	1.002	1	1.000	0	0	27.05	1.001	1	1.000	0	0
	27.26	1	27.14	0.996	1	1.000	27.37	1.004	1	1.000	0	0	27.36	1.004	1	1.000	0	0
	27.59	1	27.61	1.001	1	1.000	27.80	1.007	1	1.000	0	0	27.94	1.012	1	1.000	0	0
exp-1-500-5-5	2.87	1	2.93	1.016	1	1.000	2.88	1.003	1	1.000	2	0	2.86	0.997	1	1.000	2	0
	2.79	1	2.79	1.000	1	1.000	2.81	1.005	1	1.000	3	0	2.78	0.997	1	1.000	3	0
	2.79	1	2.75	0.989	1	1.000	2.78	0.997	1	1.000	1	0	2.81	1.005	1	1.000	1	0
fast0507	418.22	1.89K	416.58	0.996	1.89K	1.000	423.50	1.013	1.89K	1.000	2.09K	0	424.39	1.015	1.89K	1.000	2.09K	0
	212.64	944	213.00	1.002	944	1.000	215.70	1.014	944	1.000	956	0	216.66	1.019	944	1.000	956	0
	156.23	671	155.48	0.995	671	1.000	157.50	1.008	671	1.000	629	0	157.20	1.006	671	1.000	629	0
fastxgemm-n2r6s0t2	409.28	73.64K	408.00	0.997	73.64K	1.000	238.78	**0.584**	41.32K	**0.562**	22.12K	5.89K	238.62	**0.584**	41.32K	**0.562**	22.12K	5.89K
	736.77	147.63K	736.49	1.000	147.63K	1.000	1259.75	*1.709*	262.78K	*1.779*	133.68K	12.31K	1258.21	*1.707*	262.78K	*1.779*	133.68K	12.31K
	228.16	40.36K	228.19	1.000	40.36K	1.000	197.90	**0.868**	27.37K	**0.679**	14.36K	5.14K	197.91	**0.868**	27.37K	**0.679**	14.36K	5.14K
fhnw-binpack4-48	∞	5.50M	∞	1.000	5.46M	0.991	∞	1.000	5.14M	0.933	2.58M	0	∞	1.000	5.14M	0.933	2.58M	0
	∞	5.76M	∞	1.000	5.77M	1.001	∞	1.000	5.41M	0.939	2.71M	0	∞	1.000	5.42M	0.940	2.71M	0
	1310.31	1.00M	1314.17	1.003	1.00M	1.000	1392.86	*1.063*	1.00M	1.000	500.23K	0	1393.67	*1.064*	1.00M	1.000	500.23K	0
fhnw-binpack4-4	∞	11.84M	∞	1.000	11.92M	1.007	∞	1.000	11.80M	0.997	5.94M	0	∞	1.000	11.74M	0.991	5.91M	0
	∞	14.25M	∞	1.000	14.27M	1.002	∞	1.000	14.16M	0.994	7.09M	0	∞	1.000	14.14M	0.992	7.08M	0
	∞	10.15M	∞	1.000	10.11M	0.996	∞	1.000	10.11M	0.997	5.19M	0	∞	1.000	10.10M	0.995	5.19M	0
fiball	366.32	8.19K	368.20	1.005	8.19K	1.000	388.90	*1.061*	8.19K	1.000	8.12K	0	387.04	*1.056*	8.19K	1.000	8.12K	0
	426.13	14.44K	425.81	0.999	14.44K	1.000	453.69	*1.065*	14.44K	1.000	11.28K	0	451.26	*1.059*	14.44K	1.000	11.28K	0
	687.39	16.56K	686.18	0.998	16.56K	1.000	732.70	*1.066*	16.56K	1.000	16.02K	0	729.09	*1.061*	16.56K	1.000	16.02K	0
gen-ip002	1349.54	5.06M	1337.77	0.991	5.06M	1.000	1363.85	1.011	5.06M	1.000	3.87M	0	1363.77	1.011	5.06M	1.000	3.87M	0
	1413.05	5.44M	1397.56	0.989	5.45M	1.001	1438.37	1.018	5.44M	1.000	4.22M	0	1427.31	1.010	5.45M	1.001	4.18M	0
	1361.43	5.35M	1335.97	0.981	5.35M	0.999	1377.26	1.012	5.35M	1.000	4.15M	0	1363.31	1.001	5.35M	0.999	4.10M	0
gen-ip054	1400.35	5.98M	1400.89	1.000	5.98M	0.999	1575.19	*1.125*	6.66M	*1.113*	5.28M	2	1597.48	*1.141*	6.70M	*1.119*	5.29M	2
	2380.31	9.95M	2247.27	**0.944**	9.42M	**0.946**	2491.95	1.047	10.27M	1.032	8.02M	2	2524.31	*1.060*	10.29M	1.034	8.04M	2
	3380.55	14.39M	3380.57	1.000	14.39M	1.001	2791.25	**0.826**	11.63M	**0.809**	9.24M	1	2746.13	**0.812**	11.47M	**0.797**	8.99M	1
germanrr	2.14%	2.33K	2.14%	1.000	2.35K	1.007	2.14%	1.000	2.37K	1.015	2.50K	0	2.14%	1.000	2.33K	1.000	2.47K	0
	1.10%	11.99K	1.08%	1.000	12.04K	1.004	1.19%	1.000	11.86K	0.989	15.71K	0	1.23%	1.000	11.64K	0.971	15.46K	0
	2.60%	2.66K	2.60%	1.000	2.67K	1.000	2.59%	1.000	2.68K	1.005	2.75K	0	2.60%	1.000	2.66K	1.000	2.74K	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
gfd-schedulen180f7d50m30k18	∞	7	∞	1.000	7	1.000	∞	1.000	7	1.000	8	0	∞	1.000	8	1.009	8	0
	∞	8	∞	1.000	8	1.000	∞	1.000	8	1.000	13	0	∞	1.000	8	1.000	13	0
	∞	11	∞	1.000	11	1.000	∞	1.000	11	1.000	12	0	∞	1.000	11	1.000	12	0
glass-sc	3110.70	275.71K	3122.95	1.004	275.71K	1.000	3132.08	1.007	275.71K	1.000	137.96K	0	3138.93	1.009	275.71K	1.000	137.96K	0
	2984.80	264.01K	2991.56	1.002	264.01K	1.000	2982.71	0.999	264.01K	1.000	132.11K	0	2999.08	1.005	264.01K	1.000	132.11K	0
	3145.58	291.15K	3138.37	0.998	291.15K	1.000	3159.01	1.004	291.15K	1.000	145.83K	0	3146.77	1.000	291.15K	1.000	145.83K	0
glass4	1502.69	1.30M	1483.01	0.987	1.30M	1.001	2154.93	*1.434*	1.61M	*1.242*	1.04M	160.19K	1861.76	*1.239*	1.43M	*1.106*	929.64K	144.29K
	1751.08	2.12M	871.37	**0.498**	776.86K	**0.366**	5316.82	*3.035*	3.78M	*1.781*	2.47M	364.76K	4200.42	*2.398*	3.16M	*1.488*	2.03M	283.98K
	2188.88	1.62M	2398.60	*1.096*	1.79M	*1.108*	842.19	**0.385**	632.14K	**0.390**	417.56K	70.00K	1248.01	**0.570**	930.44K	**0.574**	623.12K	99.53K
gmu-35-40	0.02%	1.50M	0.02%	1.000	1.50M	0.998	0.02%	1.000	1.49M	0.993	1.73M	0	0.02%	1.000	1.49M	0.994	1.73M	0
	0.02%	4.42M	0.02%	1.000	4.41M	0.999	0.02%	1.000	4.30M	0.972	3.84M	0	0.02%	1.000	4.30M	0.973	3.84M	0
	0.03%	2.17M	0.03%	1.000	2.18M	1.001	0.03%	1.000	2.55M	1.174	2.35M	0	0.03%	1.000	2.54M	1.171	2.34M	0
gmu-35-50	0.04%	1.16M	0.04%	1.000	1.16M	0.997	0.04%	1.000	1.15M	0.994	1.03M	0	0.04%	1.000	1.15M	0.994	1.03M	0
	0.04%	2.01M	0.04%	1.000	2.01M	0.999	0.04%	1.000	2.00M	0.991	1.73M	0	0.04%	1.000	1.99M	0.991	1.73M	0
	0.05%	1.33M	0.05%	1.000	1.32M	0.997	0.05%	1.000	1.30M	0.979	1.18M	0	0.05%	1.000	1.30M	0.982	1.18M	0
graph20-20-1rand	5.75	176	5.76	1.001	176	1.000	5.75	1.000	176	1.000	174	0	5.76	1.001	176	1.000	174	0
	9.71	245	10.11	1.037	236	0.974	9.76	1.005	245	1.000	289	0	10.15	1.041	236	0.974	294	0
	5.51	198	5.55	1.006	198	1.000	5.58	1.011	198	1.000	196	0	5.60	1.014	198	1.000	196	0
graphdraw-domain	666.92	1.18M	695.38	1.043	1.15M	0.974	983.59	*1.474*	1.48M	*1.251*	862.36K	795.12K	788.16	*1.182*	1.22M	1.032	705.15K	648.81K
	826.15	1.47M	829.35	1.004	1.56M	*1.064*	1144.98	*1.385*	1.67M	*1.139*	943.82K	822.71K	1234.04	*1.493*	1.78M	*1.213*	1.01M	898.64K
	1898.15	3.35M	1967.51	1.037	3.26M	0.973	1928.06	1.016	3.35M	1.000	1.79M	0	2004.10	*1.056*	3.26M	0.973	1.76M	0
h80x6320d	89.84	8	90.01	1.002	8	1.000	90.18	1.004	8	1.000	40	7	90.36	1.006	8	1.000	40	7
	86.81	4	87.10	1.003	4	1.000	87.33	1.006	4	1.000	8	0	87.01	1.002	4	1.000	8	0
	91.20	4	91.12	0.999	4	1.000	91.19	1.000	4	1.000	21	0	91.10	0.999	4	1.000	21	0
highschool1-aigio	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
hypothyroid-k1	20.10	1	20.01	0.996	1	1.000	19.87	0.989	1	1.000	1	0	19.87	0.989	1	1.000	1	0
	19.87	1	19.93	1.003	1	1.000	19.77	0.995	1	1.000	1	0	19.63	0.989	1	1.000	1	0
	20.19	1	19.93	0.988	1	1.000	19.90	0.986	1	1.000	1	0	19.99	0.991	1	1.000	1	0
ic97_potential	0.81%	7.17M	0.82%	1.000	7.13M	0.994	0.65%	1.000	5.77M	0.804	3.12M	3.09M	0.63%	1.000	5.64M	0.787	3.05M	3.03M
	0.78%	6.21M	0.78%	1.000	6.21M	0.999	0.83%	1.000	4.40M	0.708	2.46M	2.42M	0.77%	1.000	4.39M	0.706	2.43M	2.40M
	0.61%	7.17M	0.61%	1.000	7.15M	0.998	0.80%	1.000	3.40M	0.475	1.89M	1.87M	0.81%	1.000	3.39M	0.473	1.88M	1.87M

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Table B.1: Detailed computational results on Miplib 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	**T**	**N**	**T**	**T_Q**	**N**	**N_Q**	**T**	**T_Q**	**N**	**N_Q**	**#CFC**	**#CFA**	**T**	**T_Q**	**N**	**N_Q**	**#CFC**	**#CFA**
icir97_tension	6929.45	2.54M	6949.15	1.003	2.54M	1.000	6461.34	**0.932**	1.86M	**0.731**	1.22M	1.19M	6455.21	**0.932**	1.86M	**0.731**	1.22M	1.19M
	4996.31	2.05M	4975.98	0.996	2.05M	1.000	5940.63	*1.189*	1.90M	**0.926**	1.24M	1.19M	4757.64	0.952	1.53M	**0.748**	1.00M	957.07K
	0.08%	2.79M	0.08%	1.000	2.78M	0.999	5609.91	**0.779**	1.84M	**0.659**	1.18M	1.15M	0.10%	1.000	2.12M	0.761	1.40M	1.38M
irish-electricity	∞	67	∞	1.000	67	1.000	∞	1.000	67	1.000	203	0	∞	1.000	67	1.000	200	0
	∞	28	∞	1.000	28	1.000	∞	1.000	28	1.000	54	0	∞	1.000	28	1.000	54	0
	∞	101	∞	1.000	101	1.000	∞	1.000	101	1.000	266	0	∞	1.000	101	1.000	263	0
irp	10.67	5	10.62	0.996	5	1.000	10.68	1.001	5	1.000	5	0	10.62	0.996	5	1.000	5	0
	12.16	7	12.17	1.001	7	1.000	12.18	1.002	7	1.000	8	0	12.27	1.008	7	1.000	8	0
	9.75	3	9.67	0.993	3	1.000	9.65	0.991	3	1.000	4	0	9.68	0.993	3	1.000	4	0
istanbul-no-cutoff	113.51	305	118.38	1.043	293	0.970	113.48	1.000	305	1.000	250	0	118.55	1.044	293	0.970	254	0
	110.19	363	111.74	1.014	357	0.987	110.11	0.999	363	1.000	267	0	112.49	1.021	357	0.987	263	0
	102.89	341	103.38	1.005	339	0.995	103.58	1.007	341	1.000	275	0	103.95	1.010	339	0.995	275	0
k1mushroom	1408.06	1	1415.01	1.005	1	1.000	1403.64	0.997	1	1.000	2	0	1419.44	1.008	1	1.000	2	0
	1460.66	1	1421.70	0.973	1	1.000	1461.59	1.001	1	1.000	4	0	1470.58	1.007	1	1.000	4	0
	1448.39	1	1451.50	1.002	1	1.000	1459.15	1.007	1	1.000	2	0	1476.01	1.019	1	1.000	2	0
lectsched-5-obj	120.00%	532.84K	120.00%	1.000	531.95K	0.998	120.00%	1.000	508.67K	0.955	439.38K	0	120.00%	1.000	507.62K	0.953	438.48K	0
	100.00%	410.28K	93.33%	1.000	410.20K	1.000	100.00%	1.000	392.67K	0.957	353.74K	0	93.33%	1.000	395.08K	0.963	362.69K	0
	106.21%	444.91K	106.21%	1.000	450.48K	1.013	106.21%	1.000	431.43K	0.970	377.40K	0	106.21%	1.000	431.25K	0.969	377.23K	0
leo1	0.61%	247.64K	0.61%	1.000	247.64K	1.000	0.61%	1.000	246.37K	0.995	148.36K	0	0.61%	1.000	246.19K	0.994	148.25K	0
	0.62%	240.73K	0.63%	1.000	238.72K	0.992	0.63%	1.000	237.28K	0.986	143.99K	0	0.63%	1.000	237.04K	0.985	143.85K	0
	0.85%	276.89K	0.85%	1.000	275.87K	0.996	0.85%	1.000	275.46K	0.995	171.34K	0	0.86%	1.000	274.14K	0.990	170.55K	0
leo2	3.74%	138.28K	3.74%	1.000	138.54K	1.002	3.75%	1.000	137.44K	0.994	80.23K	0	3.74%	1.000	137.76K	0.996	80.41K	0
	2.91%	97.89K	2.91%	1.000	97.97K	1.001	2.91%	1.000	97.55K	0.997	53.91K	0	2.91%	1.000	97.74K	0.998	54.02K	0
	4.44%	141.38K	4.44%	1.000	141.50K	1.001	4.44%	1.000	140.76K	0.996	84.30K	0	4.44%	1.000	141.07K	0.998	84.44K	0
lotsize	0.82%	14.73K	0.82%	1.000	14.77K	1.002	0.73%	1.000	13.19K	0.896	15.75K	14.81K	0.73%	1.000	13.19K	0.896	15.76K	14.81K
	0.86%	22.30K	0.86%	1.000	22.28K	0.999	0.95%	1.000	16.96K	0.761	17.67K	17.27K	0.95%	1.000	17.00K	0.763	17.71K	17.31K
	1.28%	16.77K	1.28%	1.000	16.67K	0.994	1.66%	1.000	16.47K	0.982	18.84K	18.22K	1.66%	1.000	16.45K	0.981	18.81K	18.19K
mad	≥ 1000%	14.11M	∞	1.000	13.05M	0.925	≥ 1000%	1.000	13.94M	0.988	7.52M	0	∞	1.000	12.88M	0.912	7.02M	0
	∞	10.88M	∞	1.000	12.90M	1.186	∞	1.000	10.67M	0.980	5.85M	0	∞	1.000	12.73M	1.170	6.92M	0
	∞	15.06M	∞	1.000	12.21M	0.810	∞	1.000	14.68M	0.974	7.91M	0	∞	1.000	11.97M	0.795	6.46M	0
map10	607.71	775	604.25	0.994	775	1.000	679.74	*1.118*	1.07K	*1.335*	1.17K	1.14K	681.81	*1.122*	1.07K	*1.335*	1.17K	1.14K
	662.83	1.46K	663.13	1.000	1.46K	1.000	640.79	0.967	1.18K	**0.823**	1.23K	1.19K	614.03	**0.926**	978	**0.691**	1.06K	1.02K
	959.90	1.15K	961.18	1.001	1.15K	1.000	857.53	**0.893**	1.02K	**0.897**	1.19K	1.17K	854.94	**0.891**	1.02K	**0.897**	1.19K	1.17K

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
map16715-04	2070.07	2.19K	2067.82	0.999	2.19K	1.000	2076.29	1.003	2.18K	0.997	2.57K	832	2092.01	1.011	2.18K	0.997	2.57K	832
	1818.01	2.03K	1812.26	0.997	2.03K	1.000	1746.48	0.961	2.03K	0.999	2.13K	719	1744.06	0.959	2.03K	0.999	2.13K	719
	1581.73	1.74K	1592.93	1.007	1.74K	1.000	1535.20	0.971	1.73K	0.996	1.83K	566	1532.22	0.969	1.73K	0.996	1.83K	566
markshare2	∞	6.47M	∞	1.000	6.48M	1.001	∞	1.000	6.47M	1.000	4.09M	0	∞	1.000	6.47M	1.000	4.09M	0
	∞	6.37M	∞	1.000	6.37M	1.000	∞	1.000	6.38M	1.001	3.91M	0	∞	1.000	6.37M	0.999	3.90M	0
	∞	5.43M	∞	1.000	5.42M	0.998	∞	1.000	5.46M	1.006	3.45M	0	∞	1.000	5.43M	0.999	3.43M	0
markshare_4_0	271.03	2.22M	243.11	**0.897**	1.95M	**0.878**	274.78	1.014	2.22M	1.000	1.12M	0	243.56	**0.899**	1.95M	**0.878**	979.46K	0
	287.79	2.31M	290.26	1.009	2.31M	1.000	291.38	1.012	2.31M	1.000	1.16M	0	291.28	1.012	2.31M	1.000	1.16M	0
	269.36	2.16M	269.82	1.002	2.16M	1.000	271.79	1.009	2.16M	1.000	1.09M	0	271.71	1.009	2.16M	1.000	1.09M	0
mas74	1674.77	4.26M	1667.70	0.996	4.23M	0.994	1704.32	1.018	4.26M	1.000	2.34M	0	1700.65	1.015	4.23M	0.994	2.33M	0
	1336.26	3.45M	1338.98	1.002	3.45M	1.000	1368.71	1.024	3.45M	1.000	1.88M	0	1357.78	1.016	3.45M	1.000	1.88M	0
	1314.69	3.14M	1409.82	*1.072*	3.24M	1.030	1341.24	1.020	3.14M	1.000	1.80M	0	1433.29	*1.090*	3.24M	1.030	1.81M	0
mas76	117.73	251.52K	118.16	1.004	251.52K	1.000	119.11	1.012	251.52K	1.000	163.34K	0	119.82	1.018	251.52K	1.000	163.34K	0
	113.96	192.21K	113.79	0.999	192.21K	1.000	115.12	1.010	192.21K	1.000	135.30K	0	115.21	1.011	192.21K	1.000	135.30K	0
	160.08	367.29K	158.86	0.992	367.29K	1.000	161.16	1.007	367.29K	1.000	236.81K	0	162.38	1.014	367.29K	1.000	236.81K	0
mc11	359.26	9.78K	349.86	0.974	9.29K	0.950	236.45	**0.659**	6.65K	**0.683**	9.05K	8.94K	236.11	**0.658**	6.65K	**0.683**	9.05K	8.94K
	130.83	2.21K	130.29	0.996	2.21K	1.000	102.67	**0.786**	1.85K	**0.842**	2.90K	2.33K	102.44	**0.785**	1.85K	**0.842**	2.90K	2.33K
	150.98	4.90K	151.15	1.001	4.90K	1.000	80.16	**0.534**	991	**0.218**	1.43K	1.33K	80.24	**0.535**	991	**0.218**	1.43K	1.33K
mcsched	310.85	15.65K	280.28	**0.902**	13.98K	**0.894**	275.30	**0.886**	12.86K	**0.823**	7.46K	7.44K	310.69	0.999	16.12K	1.030	9.27K	9.25K
	225.30	10.51K	212.75	**0.945**	10.39K	0.989	249.98	*1.109*	12.78K	*1.214*	7.32K	7.30K	213.76	**0.949**	9.62K	**0.916**	5.54K	5.42K
	331.27	18.64K	315.96	0.954	17.56K	**0.942**	299.68	**0.905**	16.76K	**0.899**	9.48K	9.33K	318.49	0.962	18.45K	0.990	10.37K	10.23K
mik-250-20-75-4	28.68	16.39K	28.81	1.004	16.39K	1.000	28.77	1.003	16.39K	1.000	12.56K	0	28.98	1.010	16.39K	1.000	12.56K	0
	31.71	17.38K	31.39	0.990	17.38K	1.000	31.88	1.005	17.38K	1.000	13.17K	0	31.88	1.005	17.38K	1.000	13.17K	0
	37.27	14.84K	37.07	0.995	14.84K	1.000	37.38	1.003	14.84K	1.000	11.08K	0	37.32	1.001	14.84K	1.000	11.08K	0
milo-v12-6-r2-40-1	7.53%	350.60K	7.52%	1.000	353.51K	1.008	7.23%	1.000	238.60K	0.681	260.32K	182.29K	7.23%	1.000	238.27K	0.680	259.92K	181.89K
	9.98%	277.89K	9.97%	1.000	279.03K	1.004	12.07%	1.000	278.18K	1.001	336.98K	265.65K	12.07%	1.000	278.88K	1.004	337.88K	266.48K
	11.92%	201.44K	11.92%	1.000	201.28K	0.999	11.82%	1.000	212.98K	1.057	242.70K	194.72K	11.81%	1.000	214.98K	1.067	245.08K	195.39K
momentum1	6.23%	109.48K	6.23%	1.000	109.46K	1.000	12.56%	1.000	76.78K	0.702	77.21K	40	12.56%	1.000	76.77K	0.702	77.20K	40
	32.07%	16.73K	32.07%	1.000	16.60K	0.992	32.12%	1.000	14.87K	0.889	13.46K	0	32.12%	1.000	14.91K	0.892	13.50K	0
	25.14%	40.15K	25.12%	1.000	40.33K	1.004	19.60%	1.000	45.54K	1.134	48.66K	7	19.60%	1.000	45.62K	1.136	48.74K	7
mushroom-best	105.91%	84.45K	105.92%	1.000	84.36K	0.999	103.92%	1.000	99.15K	1.174	96.25K	50.12K	103.95%	1.000	98.99K	1.172	96.10K	50.02K
	102.91%	83.05K	102.91%	1.000	83.08K	1.000	111.85%	1.000	92.14K	1.109	84.39K	40.33K	111.67%	1.000	92.69K	1.116	84.89K	40.59K
	125.49%	87.31K	125.49%	1.000	87.26K	0.999	129.28%	1.000	89.19K	1.022	80.03K	44.59K	129.34%	1.000	89.04K	1.020	79.90K	44.52K

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
mzzv11	291.71	1.79K	376.26	*1.289*	1.95K	*1.087*	403.75	*1.383*	2.50K	*1.381*	2.77K	2.48K	303.23	1.039	1.77K	0.994	1.87K	1.39K
	365.46	1.86K	323.48	**0.885**	1.37K	**0.747**	374.01	1.023	2.12K	*1.130*	2.06K	1.90K	344.23	**0.942**	1.37K	**0.749**	1.43K	1.25K
	234.38	882	242.65	1.035	955	*1.074*	223.54	0.954	652	**0.766**	753	619	223.15	0.952	428	**0.538**	575	352
mzzv42z	191.88	206	191.41	0.998	206	1.000	178.20	**0.929**	375	*1.552*	397	367	165.77	**0.865**	264	*1.190*	320	273
	222.71	372	222.66	1.000	361	0.977	165.23	**0.743**	166	**0.564**	267	233	160.83	**0.723**	199	**0.633**	280	249
	147.72	165	122.79	**0.832**	62	**0.611**	149.66	1.013	133	**0.879**	202	175	149.07	1.009	157	0.970	232	214
n2seq36q	688.00	2.40K	690.06	1.003	2.40K	1.000	692.50	1.007	2.40K	1.000	1.74K	0	696.72	1.013	2.40K	1.000	1.74K	0
	433.70	1.47K	457.90	*1.056*	1.68K	*1.138*	436.51	1.006	1.47K	1.000	1.10K	0	458.53	*1.057*	1.68K	*1.138*	1.15K	0
	205.27	781	204.90	0.998	781	1.000	205.62	1.002	781	1.000	683	0	206.67	1.007	781	1.000	683	0
n3div36	2.43%	218.00K	2.44%	1.000	217.71K	0.999	2.52%	1.000	199.22K	0.914	140.89K	0	2.51%	1.000	199.79K	0.917	141.22K	0
	2.38%	230.73K	2.38%	1.000	230.10K	0.997	2.45%	1.000	215.45K	0.934	148.40K	0	2.46%	1.000	213.79K	0.927	147.30K	0
	2.41%	229.13K	2.29%	1.000	235.01K	1.026	2.48%	1.000	213.28K	0.931	148.52K	0	2.39%	1.000	220.04K	0.960	152.79K	0
n5-3	40.59	1.12K	40.55	0.999	1.12K	1.000	40.74	1.004	1.12K	1.000	1.36K	0	40.89	1.007	1.12K	1.000	1.36K	0
	31.57	691	31.35	0.993	691	1.000	31.57	1.000	691	1.000	804	0	31.56	1.000	691	1.000	804	0
	34.39	991	34.46	1.002	991	1.000	34.56	1.005	991	1.000	1.26K	0	34.69	1.008	991	1.000	1.26K	0
neos-1122047	10.07	1	9.90	0.985	1	1.000	10.27	1.018	1	1.000	0	0	10.15	1.007	1	1.000	0	0
	10.03	1	9.89	0.987	1	1.000	10.12	1.008	1	1.000	0	0	9.97	0.995	1	1.000	0	0
	10.44	1	10.02	0.963	1	1.000	10.20	0.979	1	1.000	0	0	10.17	0.976	1	1.000	0	0
neos-1171448	7.37	1	7.33	0.995	1	1.000	7.33	0.995	1	1.000	1	0	7.32	0.994	1	1.000	1	0
	20.31	12	20.19	0.994	12	1.000	20.43	1.006	12	1.000	13	0	20.18	0.994	12	1.000	13	0
	21.04	13	21.10	1.003	13	1.000	21.12	1.004	13	1.000	13	0	21.11	1.003	13	1.000	13	0
neos-1171737	1.04%	5.73K	1.04%	1.000	5.72K	0.998	0.52%	1.000	9.84K	1.705	8.39K	5.22K	0.52%	1.000	9.80K	1.698	8.36K	5.20K
	1.04%	3.96K	1.04%	1.000	3.91K	0.988	1.04%	1.000	15.59K	3.869	13.12K	9.10K	1.04%	1.000	15.59K	3.868	13.12K	9.10K
	1.03%	4.38K	1.03%	1.000	4.37K	0.997	1.04%	1.000	5.79K	1.314	5.51K	2.55K	1.04%	1.000	5.71K	1.298	5.45K	2.51K
neos-1354092	∞	284	∞	1.000	284	1.000	∞	1.000	284	1.000	252	0	∞	1.000	284	1.000	252	0
	∞	324	∞	1.000	324	1.000	∞	1.000	325	1.002	305	0	∞	1.000	324	1.000	304	0
	∞	2.40K	∞	1.000	2.40K	1.002	∞	1.000	2.40K	1.002	2.39K	0	∞	1.000	2.42K	1.009	2.41K	0
neos-1445765	58.58	79	58.70	1.002	79	1.000	58.73	1.003	79	1.000	64	0	58.67	1.002	79	1.000	64	0
	61.53	71	60.94	0.991	71	1.000	60.96	0.991	71	1.000	60	0	61.12	0.993	71	1.000	60	0
	57.80	51	57.62	0.997	51	1.000	57.91	1.002	51	1.000	40	0	58.05	1.004	51	1.000	40	0
neos-1456979	3127.05	20.24K	5820.85	*1.861*	31.55K	*1.556*	3128.23	1.000	20.24K	1.000	19.63K	0	5843.33	*1.868*	31.55K	*1.556*	30.70K	0
	3749.33	18.71K	3941.62	*1.051*	20.31K	*1.085*	3753.42	1.001	18.71K	1.000	19.30K	0	3925.60	1.047	20.31K	*1.085*	20.34K	0
	4.40%	32.26K	5713.64	**0.794**	32.26K	1.000	4.40%	1.000	32.11K	0.996	33.20K	0	5733.66	**0.796**	32.26K	1.000	33.25K	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
neos-1582420	31.05	426	31.18	1.004	426	1.000	31.24	1.006	426	1.000	475	0	31.26	1.007	426	1.000	475	0
	20.71	59	20.73	1.001	59	1.000	20.72	1.000	59	1.000	181	0	20.77	1.003	59	1.000	181	0
	15.60	22	15.59	0.999	22	1.000	15.59	0.999	22	1.000	87	0	15.67	1.004	22	1.000	87	0
neos-2075418-temuka	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
neos-2657525-crna	∞	2.34M	∞	1.000	2.34M	0.998	∞	1.000	2.34M	0.998	1.72M	0	∞	1.000	2.34M	1.000	1.72M	0
	∞	1.82M	∞	1.000	1.82M	1.001	∞	1.000	1.82M	0.999	1.64M	0	∞	1.000	1.82M	0.999	1.64M	0
	∞	1.92M	∞	1.000	1.92M	1.003	∞	1.000	1.91M	0.997	1.35M	0	∞	1.000	1.91M	0.996	1.34M	0
neos-2746589-doon	0.11%	62.82K	0.17%	1.000	53.97K	0.859	0.11%	1.000	72.88K	1.160	69.79K	42.23K	0.11%	1.000	81.83K	1.302	68.19K	26.36K
	0.46%	16.88K	0.46%	1.000	16.63K	0.985	0.47%	1.000	16.05K	0.951	29.27K	0	0.47%	1.000	16.05K	0.951	29.24K	0
	0.76%	35.16K	0.76%	1.000	34.71K	0.987	0.77%	1.000	31.31K	0.891	47.27K	0	0.77%	1.000	31.28K	0.890	47.23K	0
neos-2978193-inde	0.13%	633.89K	0.13%	1.000	633.22K	0.999	0.13%	1.000	563.56K	0.889	285.83K	0	0.13%	1.000	564.61K	0.891	286.31K	0
	2565.91	194.12K	2557.33	0.997	194.12K	1.000	2786.03	*1.086*	194.12K	1.000	97.06K	0	2794.50	*1.089*	194.12K	1.000	97.06K	0
	5058.88	440.98K	5095.99	1.007	440.98K	1.000	5587.66	*1.105*	440.98K	1.000	220.49K	0	5533.58	*1.094*	440.98K	1.000	220.49K	0
neos-2987310-joes	15.31	1	15.19	0.993	1	1.000	15.23	0.995	1	1.000	0	0	15.05	0.984	1	1.000	0	0
	13.78	1	13.63	0.990	1	1.000	13.62	0.989	1	1.000	0	0	13.62	0.989	1	1.000	0	0
	23.84	1	23.49	0.986	1	1.000	23.70	0.994	1	1.000	0	0	23.68	0.994	1	1.000	0	0
neos-3004026-krka	65.69	5.22K	65.22	0.993	5.22K	1.000	67.77	1.031	5.22K	1.000	4.18K	0	67.57	1.028	5.22K	1.000	4.18K	0
	198.77	8.43K	198.13	0.997	8.43K	1.000	204.62	1.029	8.43K	1.000	7.98K	0	204.38	1.028	8.43K	1.000	7.98K	0
	78.00	5.27K	77.39	0.992	5.27K	1.000	80.58	1.033	5.27K	1.000	4.82K	0	80.49	1.032	5.27K	1.000	4.82K	0
neos-3024952-loue	1930.92	72.97K	1812.43	**0.939**	72.94K	1.000	2099.72	*1.087*	72.62K	0.995	70.61K	479	2561.69	*1.326*	72.76K	0.997	70.67K	546
	4989.42	262.03K	0.03%	1.443	640.05K	2.442	0.05%	1.443	408.62K	1.559	361.54K	192.06K	0.04%	1.443	392.35K	1.497	347.99K	178.21K
	4025.29	373.32K	0.14%	1.788	646.29K	1.731	5490.38	*1.364*	392.49K	*1.051*	334.48K	299.92K	0.02%	1.788	608.42K	1.630	501.01K	464.95K
neos-3046615-murg	176.50%	6.54M	176.50%	1.000	6.55M	1.001	178.28%	1.000	5.27M	0.807	5.86M	446.66K	178.20%	1.000	5.28M	0.808	5.88M	447.85K
	177.83%	6.61M	177.83%	1.000	6.61M	1.000	179.30%	1.000	5.01M	0.757	5.79M	296.81K	179.29%	1.000	5.02M	0.759	5.80M	297.53K
	175.76%	5.60M	175.92%	1.000	5.57M	0.995	177.64%	1.000	4.74M	0.846	5.50M	307.00K	177.64%	1.000	4.75M	0.849	5.51M	308.24K
neos-3083819-nubu	8.26	899	8.26	1.000	899	1.000	8.55	1.031	899	1.000	1.56K	0	8.68	1.045	899	1.000	1.56K	0
	16.75	2.62K	16.98	1.013	2.66K	1.015	17.66	*1.051*	2.62K	1.000	4.14K	0	17.91	*1.065*	2.66K	1.015	4.19K	0
	16.77	3.08K	14.39	**0.866**	2.25K	**0.738**	17.58	1.046	3.08K	1.000	4.32K	0	15.22	**0.913**	2.25K	**0.738**	3.41K	0
neos-3216931-puriri	127.29%	6.50K	127.29%	1.000	6.52K	1.002	126.93%	1.000	6.58K	1.012	6.98K	5	126.93%	1.000	6.60K	1.015	7.00K	5
	118.01%	3.76K	118.01%	1.000	3.75K	0.998	130.91%	1.000	4.74K	1.256	5.21K	8	130.91%	1.000	4.75K	1.258	5.23K	8
	141.04%	4.12K	141.04%	1.000	4.10K	0.996	109.32%	1.000	3.73K	0.908	4.47K	130	109.07%	1.000	3.77K	0.918	4.51K	133

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Table B.1: Detailed computational results on Miplib 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
neos-3381206-awhea	1.84	56	1.82	0.993	56	1.000	1.82	0.993	56	1.000	42	2	1.82	0.993	56	1.000	42	2
	1.37	12	1.34	0.987	12	1.000	1.36	0.996	12	1.000	10	0	1.36	0.996	12	1.000	10	0
	1.44	1	1.40	0.984	1	1.000	1.40	0.984	1	1.000	1	0	1.39	0.980	1	1.000	1	0
neos-3402294-bobin	5067.07	66.43K	1715.81	**0.339**	13.28K	**0.201**	1352.37	**0.267**	9.91K	**0.150**	7.28K	0	955.40	**0.189**	5.99K	**0.091**	4.70K	0
	3164.15	46.72K	917.09	**0.290**	5.45K	**0.119**	3171.42	1.002	46.72K	1.000	27.52K	0	915.48	**0.290**	5.45K	**0.119**	4.05K	0
	991.69	8.28K	2683.98	*2.705*	26.45K	*3.170*	999.76	1.008	8.28K	1.000	5.77K	0	2700.27	*2.721*	26.45K	*3.170*	19.82K	0
neos-3402454-bohle	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
neos-3555904-turama	61.86%	1.07K	61.86%	1.000	1.07K	1.000	61.86%	1.000	1.07K	1.002	758	0	61.86%	1.000	1.07K	1.000	756	0
	18.01%	809	18.01%	1.000	809	1.000	18.01%	1.000	809	1.000	569	0	18.01%	1.000	809	1.000	569	0
	∞	105	∞	1.000	105	1.000	∞	1.000	105	1.000	63	0	∞	1.000	105	1.000	63	0
neos-3627168-kasai	0.13%	4.33M	0.13%	1.000	4.33M	1.001	0.07%	1.000	3.03M	0.701	2.27M	2.27M	0.07%	1.000	3.03M	0.700	2.27M	2.27M
	0.19%	4.65M	0.19%	1.000	4.66M	1.003	0.32%	1.000	3.85M	0.828	3.20M	3.19M	0.32%	1.000	3.85M	0.828	3.20M	3.19M
	0.02%	4.31M	0.02%	1.000	4.30M	0.998	0.06%	1.000	3.96M	0.919	2.59M	2.59M	0.06%	1.000	3.96M	0.918	2.59M	2.59M
neos-3656078-kumeu	∞	724	∞	1.000	726	1.002	∞	1.000	724	1.000	830	0	∞	1.000	724	1.000	830	0
	∞	562	∞	1.000	558	0.994	∞	1.000	560	0.997	617	0	∞	1.000	562	1.000	620	0
	∞	124	∞	1.000	125	1.004	∞	1.000	125	1.004	104	0	∞	1.000	125	1.004	104	0
neos-3754480-nidda	∞	17.77M	∞	1.000	17.65M	0.993	∞	1.000	17.15M	0.965	10.66M	0	∞	1.000	17.29M	0.973	10.74M	0
	∞	19.06M	∞	1.000	19.11M	1.003	∞	1.000	18.51M	0.972	11.43M	0	∞	1.000	18.50M	0.971	11.42M	0
	∞	17.85M	∞	1.000	17.85M	1.000	∞	1.000	17.24M	0.966	10.67M	0	∞	1.000	17.21M	0.964	10.65M	0
neos-3988577-wolgan	∞	12.91K	∞	1.000	12.94K	1.002	∞	1.000	12.89K	0.999	12.19K	0	∞	1.000	12.87K	0.997	12.17K	0
	∞	2.03K	∞	1.000	2.03K	0.999	∞	1.000	2.02K	0.997	1.75K	0	∞	1.000	2.02K	0.997	1.75K	0
	∞	557	∞	1.000	557	1.000	∞	1.000	571	1.021	563	0	∞	1.000	562	1.008	557	0
neos-4300652-rahue	388.23%	1.82K	388.23%	1.000	1.82K	1.002	388.23%	1.000	1.82K	1.002	1.84K	0	388.23%	1.000	1.81K	0.999	1.84K	0
	298.50%	1.57K	298.97%	1.000	1.57K	0.997	298.50%	1.000	1.57K	1.000	1.60K	0	298.97%	1.000	1.57K	0.997	1.59K	0
	343.43%	3.34K	343.43%	1.000	3.34K	0.999	326.56%	1.000	3.38K	1.010	3.53K	0	343.43%	1.000	3.35K	1.003	3.51K	0
neos-4338804-snowy	2.07%	4.92M	2.07%	1.000	4.87M	0.990	2.07%	1.000	4.79M	0.973	2.69M	0	2.07%	1.000	4.79M	0.973	2.71M	0
	2.07%	4.84M	1.66%	1.000	5.65M	1.169	2.07%	1.000	4.79M	0.991	2.64M	0	1.66%	1.000	5.47M	1.131	2.96M	0
	2.07%	4.89M	2.07%	1.000	4.91M	1.005	2.07%	1.000	4.81M	0.983	2.68M	0	2.07%	1.000	4.83M	0.988	2.72M	0
neos-4387871-tavua	16.74%	53.10K	16.78%	1.000	51.29K	0.966	16.80%	1.000	50.88K	0.958	58.58K	0	16.80%	1.000	50.92K	0.959	58.63K	0
	15.74%	65.19K	15.72%	1.000	65.98K	1.012	15.76%	1.000	64.12K	0.984	71.91K	0	15.76%	1.000	64.12K	0.984	71.90K	0
	14.46%	35.48K	14.47%	1.000	35.31K	0.995	14.47%	1.000	35.27K	0.994	42.32K	0	14.47%	1.000	35.36K	0.996	42.41K	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
neos-4413714-turia	343.05	3	340.85	0.994	3	1.000	338.66	0.987	3	1.000	8	0	343.84	1.002	3	1.000	8	0
	382.86	2	384.04	1.003	2	1.000	381.39	0.996	2	1.000	6	0	383.59	1.002	2	1.000	6	0
	453.43	3	456.23	1.006	3	1.000	456.28	1.006	3	1.000	8	0	450.26	0.993	3	1.000	8	0
neos-4532248-waihi	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
neos-4647030-tutaki	0.01%	14.89K	0.01%	1.000	14.99K	1.007	0.01%	1.000	14.74K	0.990	16.79K	0	0.01%	1.000	14.66K	0.985	16.69K	0
	0.01%	7.81K	0.01%	1.000	7.97K	1.021	0.01%	1.000	7.97K	1.020	10.97K	0	0.01%	1.000	7.93K	1.015	10.92K	0
	0.01%	14.42K	0.01%	1.000	14.39K	0.998	0.01%	1.000	14.41K	0.999	19.52K	0	0.01%	1.000	14.46K	1.003	19.58K	0
neos-4722843-widden	587.46	1.16K	779.43	*1.326*	3.56K	*2.899*	600.97	1.023	1.16K	1.000	1.14K	0	805.36	*1.370*	3.56K	*2.899*	2.57K	0
	544.99	1.31K	633.94	*1.163*	1.75K	*1.317*	551.74	1.012	1.31K	1.000	1.14K	0	647.42	*1.188*	1.75K	*1.317*	1.57K	0
	890.25	2.52K	900.20	1.011	2.38K	**0.945**	908.66	1.021	2.52K	1.000	2.24K	0	919.98	1.033	2.38K	**0.945**	2.18K	0
neos-4738912-atrato	2104.14	195.96K	1680.49	**0.799**	162.83K	**0.831**	1412.58	**0.671**	123.82K	**0.632**	167.34K	0	2309.46	*1.098*	224.28K	*1.144*	333.60K	0
	1431.25	117.57K	1440.78	1.007	117.57K	1.000	964.38	**0.674**	71.56K	**0.609**	87.59K	0	966.63	**0.676**	71.56K	**0.609**	87.59K	0
	698.43	78.03K	698.57	1.000	78.03K	1.000	909.98	*1.302*	94.77K	*1.214*	102.40K	0	912.41	*1.306*	94.77K	*1.214*	102.40K	0
neos-4763324-toguru	44.18%	13.30K	44.18%	1.000	13.25K	0.996	44.21%	1.000	13.08K	0.983	16.66K	0	44.18%	1.000	13.08K	0.983	16.66K	0
	42.81%	9.28K	42.81%	1.000	9.29K	1.001	42.81%	1.000	9.28K	1.000	9.74K	0	42.81%	1.000	9.28K	1.000	9.74K	0
	44.75%	5.68K	44.75%	1.000	5.68K	1.000	44.75%	1.000	5.68K	1.000	6.38K	0	44.75%	1.000	5.68K	1.000	6.38K	0
neos-4954672-berkel	7.42%	1.11M	7.41%	1.000	1.12M	1.002	7.26%	1.000	996.58K	0.895	868.86K	100.03K	7.26%	1.000	995.86K	0.894	868.23K	99.96K
	7.33%	881.86K	7.33%	1.000	882.93K	1.001	7.59%	1.000	1.12M	1.273	1.02M	82.74K	7.59%	1.000	1.12M	1.270	1.02M	82.57K
	8.87%	755.76K	8.86%	1.000	760.14K	1.006	9.21%	1.000	714.63K	0.946	581.43K	140.97K	9.21%	1.000	715.65K	0.947	582.29K	141.08K
neos-5049753-cuanza	∞	8	∞	1.000	7	0.991	∞	1.000	8	1.000	7	0	∞	1.000	8	1.000	7	0
	∞	15	∞	1.000	15	1.000	∞	1.000	15	1.000	15	0	∞	1.000	15	1.000	14	0
	∞	8	∞	1.000	8	1.000	∞	1.000	8	1.000	8	0	∞	1.000	8	1.000	8	0
neos-5052403-cygnet	1.88%	121	1.88%	1.000	123	1.009	1.88%	1.000	123	1.009	123	0	1.88%	1.000	123	1.009	123	0
	1.35%	77	1.35%	1.000	76	0.994	1.35%	1.000	77	1.000	77	0	1.35%	1.000	77	1.000	77	0
	1.38%	136	1.38%	1.000	136	1.000	1.38%	1.000	135	0.996	126	0	1.38%	1.000	136	1.000	126	0
neos-5093327-huahum	6.82%	64.85K	6.82%	1.000	64.89K	1.001	6.92%	1.000	63.10K	0.973	33.10K	0	6.92%	1.000	63.30K	0.976	33.19K	0
	12.31%	50.18K	12.33%	1.000	49.81K	0.993	12.38%	1.000	49.11K	0.979	28.17K	0	12.39%	1.000	48.86K	0.974	28.04K	0
	11.85%	49.07K	11.88%	1.000	48.89K	0.996	11.97%	1.000	48.15K	0.981	27.36K	0	11.99%	1.000	47.83K	0.975	27.19K	0
neos-5104907-jarama	∞	5	∞	1.000	5	1.000	∞	1.000	5	1.000	19	0	∞	1.000	5	1.000	19	0
	∞	3	∞	1.000	3	1.000	∞	1.000	3	1.000	19	0	∞	1.000	3	1.000	19	0
	∞	5	∞	1.000	5	1.000	∞	1.000	5	1.000	21	0	∞	1.000	5	1.000	21	0

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Table B.1: Detailed computational results on Miplib 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
neos-5107597-kakapo	6520.28	1.77M	6680.57	1.025	1.86M	1.050	6590.69	1.011	1.77M	1.000	897.49K	0	6784.12	1.040	1.86M	1.050	941.41K	0
	42.58%	1.95M	48.52%	1.000	2.01M	1.033	4114.42	**0.572**	1.03M	**0.531**	520.07K	511.16K	3704.06	**0.515**	912.46K	**0.469**	458.21K	453.39K
	122.34%	1.77M	128.09%	1.000	1.79M	1.011	123.08%	1.000	1.75M	0.985	963.11K	0	128.17%	1.000	1.79M	1.007	991.43K	0
neos-5114902-kasavu	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
neos-5188808-nattai	1371.31	12.89K	1352.99	0.987	12.89K	1.000	1550.80	*1.131*	12.75K	0.990	6.56K	436	1559.80	*1.137*	12.75K	0.990	6.56K	436
	1405.67	13.69K	1414.74	1.006	13.69K	1.000	1288.34	**0.917**	11.41K	**0.835**	5.83K	439	1291.92	**0.919**	11.41K	**0.835**	5.83K	439
	1432.79	15.25K	1439.79	1.005	15.25K	1.000	1456.21	1.016	14.66K	0.962	7.64K	425	1452.74	1.014	14.66K	0.962	7.64K	425
neos-5195221-niemur	1295.14	49.58K	835.46	**0.645**	19.71K	**0.399**	1328.87	1.026	49.58K	1.000	25.53K	0	851.07	**0.657**	19.71K	**0.399**	10.26K	0
	2904.10	207.72K	1039.55	**0.358**	38.12K	**0.184**	3007.46	1.036	207.72K	1.000	106.85K	0	1059.56	**0.365**	38.12K	**0.184**	19.67K	0
	1881.58	102.70K	1024.49	**0.545**	30.02K	**0.293**	1928.87	1.025	102.70K	1.000	52.43K	0	1044.20	**0.555**	30.02K	**0.293**	15.93K	0
neos-631710	14.74%	1	14.74%	1.000	1	1.000	14.74%	1.000	1	1.000	1	0	14.74%	1.000	1	1.000	1	0
	11.55%	1	11.55%	1.000	1	1.000	11.55%	1.000	1	1.000	1	0	11.55%	1.000	1	1.000	1	0
	11.55%	1	11.55%	1.000	1	1.000	11.55%	1.000	1	1.000	2	0	11.55%	1.000	1	1.000	2	0
neos-662469	6851.27	58.01K	0.00%	1.051	63.13K	1.088	7055.57	1.030	58.01K	1.000	66.34K	0	0.00%	1.051	61.30K	1.057	69.32K	0
	0.00%	55.27K	7149.68	0.993	57.46K	1.040	0.00%	1.000	53.13K	0.961	60.67K	0	0.00%	1.000	55.40K	1.002	63.24K	0
	0.00%	59.14K	0.00%	1.000	53.97K	0.913	0.00%	1.000	57.91K	0.979	63.55K	0	0.00%	1.000	51.19K	0.866	56.99K	0
neos-787933	1.63	1	1.64	1.004	1	1.000	1.69	1.023	1	1.000	0	0	1.63	1.000	1	1.000	0	0
	1.65	1	1.67	1.008	1	1.000	1.69	1.015	1	1.000	0	0	1.67	1.008	1	1.000	0	0
	1.66	1	1.61	0.981	1	1.000	1.67	1.004	1	1.000	0	0	1.66	1.000	1	1.000	0	0
neos-827175	7.43	1	7.49	1.007	1	1.000	7.51	1.009	1	1.000	1	0	7.56	1.015	1	1.000	1	0
	6.88	1	6.89	1.001	1	1.000	6.84	0.995	1	1.000	0	0	6.92	1.005	1	1.000	0	0
	5.65	1	5.64	0.998	1	1.000	5.70	1.008	1	1.000	0	0	5.58	0.989	1	1.000	0	0
neos-848589	1744.82	62	1750.82	1.003	62	1.000	1763.41	1.011	62	1.000	75	0	1770.54	1.015	62	1.000	75	0
	1.97%	1.01K	1.97%	1.000	1.01K	0.999	1.97%	1.000	980	0.969	1.04K	0	1.97%	1.000	964	0.954	1.02K	0
	835.88	47	833.54	0.997	47	1.000	840.71	1.006	47	1.000	43	0	843.83	1.009	47	1.000	43	0
neos-860300	16.88	2	16.88	1.000	2	1.000	16.92	1.002	2	1.000	3	0	17.07	1.011	2	1.000	3	0
	16.44	2	16.34	0.994	2	1.000	16.41	0.998	2	1.000	3	0	16.39	0.997	2	1.000	3	0
	19.74	3	19.58	0.992	3	1.000	19.60	0.993	3	1.000	3	0	19.51	0.989	3	1.000	3	0
neos-873061	0.13%	2.56K	0.13%	1.000	2.50K	0.976	0.13%	1.000	2.44K	0.957	4.93K	0	0.13%	1.000	2.47K	0.965	4.97K	0
	0.19%	5.13K	0.19%	1.000	5.09K	0.993	0.19%	1.000	5.15K	1.005	9.75K	0	0.19%	1.000	4.91K	0.958	9.30K	0
	0.12%	18.68K	0.12%	1.000	18.60K	0.996	0.12%	1.000	18.21K	0.975	31.35K	0	0.12%	1.000	18.19K	0.974	31.33K	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
neos-911970	132.16	79.42K	133.18	1.008	79.42K	1.000	135.01	1.021	79.42K	1.000	44.33K	0	135.49	1.025	79.42K	1.000	44.33K	0
	19.06	8.51K	19.37	1.015	8.51K	1.000	19.51	1.022	8.51K	1.000	5.71K	0	19.51	1.022	8.51K	1.000	5.71K	0
	0.02%	9.50M	0.02%	1.000	9.39M	0.989	0.02%	1.000	10.13M	1.066	5.50M	1.52M	0.02%	1.000	10.08M	1.062	5.48M	1.51M
neos-933966	0.63%	886	0.63%	1.000	886	1.000	0.63%	1.000	886	1.000	880	0	0.63%	1.000	882	0.996	877	0
	1992.87	339	1986.39	0.997	339	1.000	1999.80	1.003	339	1.000	340	0	1987.03	0.997	339	1.000	340	0
	5250.25	1.03K	5246.61	0.999	1.03K	1.000	5251.31	1.000	1.03K	1.000	1.05K	0	5226.00	0.995	1.03K	1.000	1.05K	0
neos-950242	488.83	339	479.93	0.982	307	**0.927**	489.58	1.002	339	1.000	293	0	482.50	0.987	307	**0.927**	269	0
	139.82	53	139.78	1.000	53	1.000	139.18	0.995	53	1.000	40	0	139.17	0.995	53	1.000	40	0
	83.65	25	83.79	1.002	25	1.000	83.99	1.004	25	1.000	15	0	83.77	1.001	25	1.000	15	0
neos-957323	380.34	117	380.65	1.001	117	1.000	385.38	1.013	117	1.000	81	0	380.49	1.000	117	1.000	81	0
	118.08	2	118.02	0.999	2	1.000	117.91	0.999	2	1.000	9	0	117.06	0.991	2	1.000	9	0
	228.14	46	229.23	1.005	46	1.000	228.92	1.003	46	1.000	42	0	230.48	1.010	46	1.000	42	0
neos-960392	799.26	121	794.35	0.994	121	1.000	797.73	0.998	121	1.000	120	0	798.96	1.000	121	1.000	120	0
	1138.41	859	1137.61	0.999	859	1.000	449.66	**0.396**	30	**0.136**	31	2	454.24	**0.400**	30	**0.136**	31	2
	1333.69	139	1334.00	1.000	139	1.000	1333.41	1.000	139	1.000	137	0	1337.85	1.003	139	1.000	137	0
neos17	14.58	8.90K	14.60	1.001	8.90K	1.000	26.87	*1.789*	16.65K	*1.862*	13.05K	381	26.87	*1.789*	16.65K	*1.862*	13.05K	381
	9.61	5.81K	9.54	0.993	5.81K	1.000	10.61	*1.094*	6.26K	*1.077*	4.50K	48	10.67	*1.100*	6.26K	*1.077*	4.50K	48
	7.20	3.43K	7.20	1.000	3.43K	1.000	7.79	*1.072*	3.43K	1.000	2.64K	52	7.74	*1.066*	3.43K	1.000	2.64K	52
neos5	208.42	599.23K	206.80	0.992	599.23K	1.000	300.23	*1.438*	703.15K	*1.173*	363.26K	92.33K	304.59	*1.459*	703.15K	*1.173*	363.26K	92.33K
	198.80	564.87K	198.20	0.997	564.87K	1.000	357.70	*1.795*	867.84K	*1.536*	446.89K	98.44K	357.31	*1.793*	867.84K	*1.536*	446.89K	98.44K
	123.53	289.22K	121.84	0.986	289.22K	1.000	189.23	*1.528*	413.30K	*1.429*	216.00K	53.37K	279.50	*2.252*	618.81K	*2.139*	321.22K	77.31K
neos859080	2.77	1.21K	2.76	0.997	1.21K	1.000	2.86	1.024	1.21K	1.000	945	0	2.77	1.000	1.21K	1.000	945	0
	7.24	7.71K	7.17	0.992	7.71K	1.000	7.22	0.998	7.71K	1.000	6.09K	0	7.21	0.996	7.71K	1.000	6.09K	0
	3.90	2.29K	3.85	0.990	2.29K	1.000	3.85	0.990	2.29K	1.000	1.61K	0	3.91	1.002	2.29K	1.000	1.61K	0
neos8	1.81	1	1.83	1.007	1	1.000	1.84	1.011	1	1.000	2	0	1.88	1.025	1	1.000	2	0
	1.82	1	1.81	0.996	1	1.000	1.79	0.989	1	1.000	2	0	1.75	0.975	1	1.000	2	0
	2.01	1	2.02	1.003	1	1.000	2.06	1.017	1	1.000	2	0	2.01	1.000	1	1.000	2	0
net12	1017.53	3.05K	1021.39	1.004	3.05K	1.000	1013.41	0.996	3.05K	1.000	1.83K	0	1022.80	1.005	3.05K	1.000	1.83K	0
	768.88	2.61K	767.23	0.998	2.61K	1.000	768.40	0.999	2.61K	1.000	1.60K	0	766.77	0.997	2.61K	1.000	1.60K	0
	538.24	2.14K	537.71	0.999	2.14K	1.000	539.79	1.003	2.14K	1.000	1.35K	0	539.54	1.002	2.14K	1.000	1.35K	0
netdiversion	616.49	17	621.41	1.008	17	1.000	618.07	1.003	17	1.000	19	0	620.16	1.006	17	1.000	19	0
	1728.93	17	1733.36	1.003	17	1.000	1730.67	1.001	17	1.000	18	0	1735.71	1.004	17	1.000	18	0
	989.33	32	988.29	0.999	32	1.000	978.81	0.989	32	1.000	32	0	996.37	1.007	32	1.000	32	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
nexp-150-20-8-5	2885.29	6.06K	2890.41	1.002	6.06K	1.000	2943.25	1.020	6.06K	1.000	16.81K	0	2946.31	1.021	6.06K	1.000	16.81K	0
	1347.12	902	1344.96	0.998	902	1.000	1347.00	1.000	902	1.000	2.52K	0	1357.67	1.008	902	1.000	2.52K	0
	1013.59	1.55K	1015.64	1.002	1.55K	1.000	1027.28	1.013	1.55K	1.000	3.78K	0	1022.36	1.009	1.55K	1.000	3.78K	0
ns1116954	∞	38	∞	1.000	37	0.993	∞	1.000	37	0.993	34	0	∞	1.000	37	0.993	34	0
	∞	43	∞	1.000	44	1.007	∞	1.000	44	1.007	39	0	∞	1.000	43	1.000	38	0
	∞	95	∞	1.000	99	1.021	∞	1.000	94	0.995	92	0	∞	1.000	95	1.000	93	0
ns1208400	1939.96	6.14K	1934.96	0.997	6.14K	1.000	1934.86	0.997	6.14K	1.000	6.33K	0	1929.50	0.995	6.14K	1.000	6.33K	0
	769.25	3.00K	819.88	*1.066*	3.10K	1.031	768.06	0.998	3.00K	1.000	3.36K	0	820.12	*1.066*	3.10K	1.031	3.43K	0
	506.80	2.42K	503.96	0.994	2.42K	1.000	507.38	1.001	2.42K	1.000	2.61K	0	503.47	0.993	2.42K	1.000	2.61K	0
ns1644855	1359.38	6	1347.47	0.991	6	1.000	1369.38	1.007	6	1.000	5	0	1366.34	1.005	6	1.000	5	0
	7.37%	53	7.37%	1.000	53	1.000	7.37%	1.000	53	1.000	49	0	7.37%	1.000	53	1.000	49	0
	441.26	1	436.87	0.990	1	1.000	439.30	0.996	1	1.000	1	0	439.44	0.996	1	1.000	1	0
ns1760995	70.41%	1	70.41%	1.000	1	1.000	70.41%	1.000	1	1.000	0	0	70.41%	1.000	1	1.000	0	0
	50.42%	1	50.42%	1.000	1	1.000	50.42%	1.000	1	1.000	0	0	50.42%	1.000	1	1.000	0	0
	43.30%	1	43.30%	1.000	1	1.000	43.30%	1.000	1	1.000	0	0	43.30%	1.000	1	1.000	0	0
ns1830653	157.34	11.07K	145.03	**0.922**	9.10K	**0.823**	157.93	1.004	11.21K	1.012	8.52K	38	149.99	0.954	9.28K	**0.840**	7.34K	16
	115.88	5.77K	118.67	1.024	6.17K	*1.067*	115.72	0.999	5.85K	1.013	4.79K	5	118.01	1.018	6.05K	1.048	4.91K	8
	122.14	6.23K	132.58	*1.085*	7.32K	*1.172*	129.73	*1.062*	7.45K	*1.193*	6.09K	65	128.88	*1.055*	7.06K	*1.132*	5.75K	53
ns1952667	2573.12	13.34K	2569.97	0.999	13.34K	1.000	2579.63	1.003	13.34K	1.000	8.16K	0	2575.92	1.001	13.34K	1.000	8.16K	0
	913.58	5.75K	942.15	1.031	5.75K	1.000	947.29	1.037	5.75K	1.000	4.29K	0	945.90	1.035	5.75K	1.000	4.29K	0
	302.03	2.15K	302.11	1.000	2.15K	1.000	302.56	1.002	2.15K	1.000	1.66K	0	303.99	1.006	2.15K	1.000	1.66K	0
nu25-pr12	4.85	5	4.88	1.005	5	1.000	4.90	1.009	5	1.000	23	0	4.89	1.007	5	1.000	23	0
	8.11	154	8.13	1.002	154	1.000	8.13	1.002	154	1.000	284	0	8.17	1.007	154	1.000	284	0
	7.75	140	7.85	1.011	140	1.000	7.85	1.011	140	1.000	282	0	7.86	1.013	140	1.000	282	0
nursesched-medium-hint03	262.07%	918	318.53%	1.000	887	0.970	318.53%	1.000	893	0.975	961	0	318.53%	1.000	893	0.975	961	0
	≥ 1000%	1.73K	≥ 1000%	1.000	1.75K	1.014	≥ 1000%	1.000	1.74K	1.010	1.76K	0	≥ 1000%	1.000	1.75K	1.015	1.77K	0
	463.36%	1.92K	463.36%	1.000	1.95K	1.015	463.36%	1.000	1.90K	0.992	1.91K	0	463.36%	1.000	1.92K	1.000	1.93K	0
nursesched-sprint02	125.16	711	126.64	1.012	712	1.001	126.71	1.012	711	1.000	796	0	127.09	1.015	712	1.001	797	0
	20.81	3	20.91	1.005	3	1.000	20.94	1.006	3	1.000	5	0	20.90	1.004	3	1.000	5	0
	92.04	319	91.77	0.997	319	1.000	92.34	1.003	319	1.000	338	0	92.50	1.005	319	1.000	338	0
nw04	25.18	9	25.21	1.001	9	1.000	25.25	1.003	9	1.000	10	0	25.18	1.000	9	1.000	10	0
	22.37	5	22.32	0.998	5	1.000	22.45	1.003	5	1.000	7	0	22.38	1.000	5	1.000	7	0
	22.92	6	22.76	0.993	6	1.000	22.86	0.997	6	1.000	8	0	22.84	0.997	6	1.000	8	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
opm2-z10-s4	25.25%	1.80K	25.25%	1.000	1.79K	0.996	26.61%	1.000	1.69K	0.942	1.58K	1.21K	26.61%	1.000	1.67K	0.933	1.57K	1.20K
	30.78%	1.30K	30.78%	1.000	1.30K	1.001	24.66%	1.000	850	0.677	706	612	24.66%	1.000	850	0.677	706	612
	23.45%	1.77K	23.85%	1.000	1.73K	0.978	29.01%	1.000	1.96K	1.099	1.83K	1.60K	29.32%	1.000	1.95K	1.096	1.83K	1.60K
p200x1188c	3.06	1	3.06	1.000	1	1.000	3.08	1.005	1	1.000	2	0	3.08	1.005	1	1.000	2	0
	3.06	1	3.07	1.002	1	1.000	3.09	1.007	1	1.000	2	0	3.09	1.007	1	1.000	2	0
	3.08	1	3.09	1.002	1	1.000	3.10	1.005	1	1.000	2	0	3.08	1.000	1	1.000	2	0
peg-solitaire-a3	∞	4.97K	∞	1.000	4.97K	1.000	∞	1.000	4.96K	0.999	3.10K	0	∞	1.000	4.97K	1.001	3.11K	0
	∞	3.34K	∞	1.000	3.32K	0.994	∞	1.000	3.31K	0.991	2.25K	0	∞	1.000	3.30K	0.988	2.25K	0
	∞	4.73K	∞	1.000	4.75K	1.003	∞	1.000	4.75K	1.003	2.54K	0	∞	1.000	4.75K	1.004	2.54K	0
pg5_34	3960.81	236.06K	3966.89	1.002	236.06K	1.000	4000.30	1.010	236.06K	1.000	157.17K	0	4005.40	1.011	236.06K	1.000	157.17K	0
	2948.10	183.53K	2942.60	0.998	183.53K	1.000	2976.68	1.010	183.53K	1.000	116.48K	0	2972.14	1.008	183.53K	1.000	116.48K	0
	2353.21	176.60K	2360.36	1.003	176.60K	1.000	2379.40	1.011	176.60K	1.000	115.07K	0	2390.22	1.016	176.60K	1.000	115.07K	0
pg	28.73	691	28.80	1.002	691	1.000	28.79	1.002	691	1.000	586	0	28.89	1.005	691	1.000	586	0
	21.56	726	21.46	0.996	726	1.000	21.56	1.000	726	1.000	749	0	21.56	1.000	726	1.000	749	0
	22.60	505	22.58	0.999	505	1.000	22.55	0.998	505	1.000	461	0	22.78	1.008	505	1.000	461	0
physiciansched3-3	4.32%	313	4.32%	1.000	313	1.000	4.32%	1.000	313	1.000	337	0	4.32%	1.000	313	1.000	337	0
	∞	258	∞	1.000	258	1.000	∞	1.000	259	1.003	271	0	∞	1.000	258	1.000	271	0
	∞	184	∞	1.000	183	0.996	∞	1.000	183	0.996	193	0	∞	1.000	184	1.000	194	0
physiciansched6-2	195.28	236	194.36	0.995	236	1.000	194.51	0.996	236	1.000	241	0	193.33	0.990	236	1.000	241	0
	2430.78	571	2446.27	1.006	537	**0.949**	2241.58	**0.922**	504	**0.900**	474	59	2539.70	1.045	543	0.958	505	71
	594.18	3.88K	593.07	0.998	3.88K	1.000	599.15	1.008	3.88K	1.000	3.46K	0	590.03	0.993	3.88K	1.000	3.46K	0
piperout-08	158.69	180	161.06	1.015	180	1.000	161.96	1.020	180	1.000	326	0	158.89	1.001	180	1.000	326	0
	134.06	285	135.21	1.009	285	1.000	135.17	1.008	285	1.000	254	0	133.81	0.998	285	1.000	251	0
	115.20	342	116.25	1.009	342	1.000	114.53	0.994	342	1.000	217	0	115.23	1.000	342	1.000	217	0
piperout-27	119.86	67	119.27	0.995	67	1.000	118.88	0.992	67	1.000	49	0	118.10	0.985	67	1.000	49	0
	127.21	65	126.86	0.997	65	1.000	128.33	1.009	65	1.000	46	0	128.66	1.011	65	1.000	46	0
	176.48	61	176.35	0.999	61	1.000	176.22	0.999	61	1.000	65	0	176.68	1.001	61	1.000	65	0
pk1	136.80	351.92K	136.37	0.997	351.92K	1.000	138.68	1.014	351.92K	1.000	177.55K	0	138.06	1.009	351.92K	1.000	177.55K	0
	152.69	394.66K	152.46	0.999	394.66K	1.000	154.14	1.009	394.66K	1.000	201.47K	0	154.06	1.009	394.66K	1.000	201.47K	0
	135.22	341.58K	132.48	0.980	341.52K	1.000	138.15	1.022	341.58K	1.000	178.50K	0	134.93	0.998	341.52K	1.000	178.23K	0
proteindesign121hz512p9	6.14%	3	6.14%	1.000	3	1.000	6.14%	1.000	3	1.000	149	0	6.14%	1.000	3	1.000	150	0
	3.44%	4.25K	3.51%	1.000	4.00K	0.944	3.44%	1.000	4.23K	0.996	3.01K	0	3.51%	1.000	4.01K	0.945	2.88K	0
	3.93%	1.24K	5.95%	1.000	1.23K	0.993	3.93%	1.000	1.24K	1.000	956	0	5.95%	1.000	1.23K	0.993	937	0

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Table B.1: Detailed computational results on Miplib 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
proteindesign122trx11p8	1.70%	352	1.70%	1.000	348	0.991	1.70%	1.000	353	1.002	442	0	1.70%	1.000	356	1.009	445	0
	2.41%	2	2.41%	1.000	2	1.000	2.41%	1.000	2	1.000	104	0	2.41%	1.000	2	1.000	105	0
	2.06%	2	2.06%	1.000	2	1.000	2.06%	1.000	2	1.000	158	0	2.06%	1.000	2	1.000	158	0
qap10	150.33	10	150.43	1.001	10	1.000	149.75	0.996	10	1.000	12	0	150.60	1.002	10	1.000	12	0
	226.60	11	226.93	1.001	11	1.000	227.22	1.003	11	1.000	12	0	228.03	1.006	11	1.000	12	0
	97.54	1	97.62	1.001	1	1.000	97.67	1.001	1	1.000	2	0	97.81	1.003	1	1.000	2	0
radiationm18-12-05	0.02%	1.68M	0.02%	1.000	1.54M	0.915	0.02%	1.000	1.62M	0.962	895.43K	0	0.02%	1.000	1.50M	0.892	832.03K	0
	0.03%	851.44K	0.03%	1.000	803.60K	0.944	0.03%	1.000	831.83K	0.977	544.34K	0	0.03%	1.000	796.55K	0.936	546.63K	0
	0.03%	855.50K	0.02%	1.000	855.05K	0.999	0.03%	1.000	844.30K	0.987	570.66K	0	0.02%	1.000	840.74K	0.983	571.69K	0
radiationm40-10-02	44.34%	139.84K	62.90%	1.000	155.77K	1.114	44.34%	1.000	135.89K	0.972	135.62K	0	62.90%	1.000	153.28K	1.096	153.12K	0
	8.26%	168.90K	8.26%	1.000	169.06K	1.001	8.26%	1.000	163.47K	0.968	152.38K	0	8.26%	1.000	162.98K	0.965	151.97K	0
	2.08%	143.60K	2.08%	1.000	144.20K	1.004	2.08%	1.000	140.29K	0.977	110.12K	0	2.08%	1.000	140.38K	0.978	110.17K	0
rail01	8.54%	43	8.49%	1.000	56	1.091	8.52%	1.000	49	1.042	83	0	8.52%	1.000	47	1.028	77	0
	8.10%	92	8.10%	1.000	92	1.000	8.10%	1.000	92	1.000	122	0	8.10%	1.000	92	1.000	122	0
	6798.56	85	6803.63	1.001	85	1.000	6873.09	1.011	85	1.000	127	0	6870.12	1.011	85	1.000	127	0
rail02	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
rail507	196.17	731	196.42	1.001	731	1.000	198.16	1.010	731	1.000	666	0	197.36	1.006	731	1.000	666	0
	269.19	1.36K	269.17	1.000	1.36K	1.000	272.74	1.013	1.36K	1.000	1.37K	0	273.02	1.014	1.36K	1.000	1.37K	0
	382.88	1.45K	385.34	1.006	1.48K	1.022	387.26	1.011	1.45K	1.000	1.61K	0	387.22	1.011	1.48K	1.022	1.61K	0
ran14x18-disj-8	1979.01	666.88K	1983.02	1.002	666.88K	1.000	2000.66	1.011	666.88K	1.000	594.29K	0	2004.58	1.013	666.88K	1.000	594.29K	0
	1927.44	525.81K	1927.83	1.000	525.81K	1.000	1797.96	**0.933**	463.89K	**0.882**	405.91K	0	1799.10	**0.933**	463.89K	**0.882**	405.91K	0
	1270.02	369.42K	1268.81	0.999	369.42K	1.000	1282.86	1.010	369.42K	1.000	327.20K	0	1283.43	1.011	369.42K	1.000	327.20K	0
rd-rplusc-21	$\geq$ 1000%	499.32K	$\geq$ 1000%	1.000	556.59K	1.115	$\geq$ 1000%	1.000	479.81K	0.961	242.05K	0	$\geq$ 1000%	1.000	543.22K	1.088	283.99K	0
	$\geq$ 1000%	793.93K	$\geq$ 1000%	1.000	778.50K	0.981	$\geq$ 1000%	1.000	783.66K	0.987	404.85K	0	$\geq$ 1000%	1.000	749.76K	0.944	399.80K	0
	$\geq$ 1000%	530.71K	$\geq$ 1000%	1.000	506.73K	0.955	$\geq$ 1000%	1.000	520.82K	0.981	272.71K	0	$\geq$ 1000%	1.000	496.88K	0.936	263.40K	0
reblock115	5792.33	778.82K	5789.14	0.999	778.82K	1.000	6761.57	*1.167*	869.96K	*1.117*	786.61K	705	6743.72	*1.164*	869.96K	*1.117*	786.61K	705
	0.14%	835.21K	0.14%	1.000	836.90K	1.002	6907.18	0.959	831.03K	0.995	738.57K	1.06K	6926.34	0.962	831.03K	0.995	738.57K	1.06K
	4854.61	652.01K	4855.57	1.000	652.01K	1.000	0.11%	1.483	991.34K	1.520	907.76K	2.28K	0.11%	1.483	991.39K	1.520	907.81K	2.28K
rmatr100-p10	153.23	725	153.10	0.999	725	1.000	154.02	1.005	725	1.000	834	0	154.32	1.007	725	1.000	834	0
	181.24	942	183.14	1.010	942	1.000	183.70	1.013	942	1.000	964	0	183.82	1.014	942	1.000	964	0
	162.49	795	163.19	1.004	795	1.000	163.22	1.004	795	1.000	855	0	163.31	1.005	795	1.000	855	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
rmatr200-p5	20.64%	395	20.64%	1.000	395	1.000	20.64%	1.000	395	1.000	415	0	20.64%	1.000	398	1.006	419	0
	20.00%	376	20.00%	1.000	376	1.000	20.00%	1.000	376	1.000	438	0	20.00%	1.000	375	0.998	437	0
	20.31%	423	20.31%	1.000	423	1.000	20.31%	1.000	426	1.006	408	0	20.31%	1.000	423	1.000	404	0
rocI-4-11	52.77	10.56K	56.94	*1.078*	11.65K	*1.102*	53.54	1.014	10.56K	1.000	5.53K	0	57.40	*1.086*	11.65K	*1.102*	6.08K	0
	75.39	16.37K	78.88	1.046	16.23K	0.991	76.01	1.008	16.37K	1.000	8.58K	0	79.54	*1.054*	16.23K	0.991	8.41K	0
	50.67	11.67K	45.55	**0.901**	9.95K	**0.854**	51.03	1.007	11.67K	1.000	6.02K	0	45.91	**0.908**	9.95K	**0.854**	5.11K	0
rocII-5-11	76.41%	325.21K	76.43%	1.000	316.79K	0.974	76.41%	1.000	308.07K	0.947	266.45K	0	76.44%	1.000	311.82K	0.959	270.72K	0
	76.38%	304.70K	76.54%	1.000	309.24K	1.015	76.38%	1.000	300.07K	0.985	267.59K	0	76.54%	1.000	303.09K	0.995	269.40K	0
	76.87%	366.57K	108.03%	1.000	354.79K	0.968	76.87%	1.000	361.33K	0.986	293.37K	0	108.03%	1.000	350.66K	0.957	290.47K	0
rococoB10-011000	13.35%	136.44K	13.37%	1.000	135.47K	0.993	13.35%	1.000	136.19K	0.998	107.67K	0	13.37%	1.000	135.59K	0.994	107.20K	0
	12.67%	167.98K	13.59%	1.000	132.00K	0.786	12.68%	1.000	167.42K	0.997	136.07K	0	13.59%	1.000	131.78K	0.785	105.22K	0
	15.97%	148.28K	15.04%	1.000	146.77K	0.990	14.97%	1.000	141.10K	0.952	112.03K	126	15.04%	1.000	146.66K	0.989	118.87K	0
rococoC10-001000	892.52	62.28K	892.62	1.000	62.28K	1.000	905.51	1.015	62.28K	1.000	66.43K	0	905.96	1.015	62.28K	1.000	66.43K	0
	780.40	55.62K	768.20	0.984	54.53K	0.980	787.91	1.010	55.62K	1.000	61.63K	0	780.56	1.000	54.53K	0.980	60.27K	0
	2053.12	160.00K	1375.92	**0.670**	85.98K	**0.538**	1348.86	**0.657**	80.81K	**0.505**	87.06K	21	1755.84	**0.855**	125.17K	**0.782**	131.77K	21
roi2alpha3n4	1446.38	12.41K	1444.89	0.999	12.41K	1.000	1497.86	1.036	12.41K	1.000	16.08K	0	1506.85	1.042	12.41K	1.000	16.08K	0
	1610.96	6.06K	1613.30	1.001	6.06K	1.000	1635.33	1.015	6.06K	1.000	7.69K	0	1643.99	1.020	6.06K	1.000	7.69K	0
	1732.94	15.95K	1752.85	1.011	15.95K	1.000	1806.95	1.043	15.95K	1.000	19.17K	0	1818.23	1.049	15.95K	1.000	19.17K	0
roi5alpha10n8	35.13%	6.32K	35.05%	1.000	6.43K	1.018	35.28%	1.000	6.05K	0.958	6.83K	0	35.17%	1.000	6.11K	0.967	6.89K	0
	42.79%	5.48K	42.79%	1.000	5.50K	1.002	43.10%	1.000	5.21K	0.950	5.79K	0	43.10%	1.000	5.20K	0.950	5.78K	0
	38.95%	7.42K	38.95%	1.000	7.31K	0.985	39.20%	1.000	6.79K	0.916	7.54K	0	39.20%	1.000	6.82K	0.920	7.58K	0
roll3000	29.09	949	29.10	1.000	949	1.000	29.09	1.000	949	1.000	1.23K	0	29.19	1.003	949	1.000	1.23K	0
	41.99	2.37K	41.84	0.997	2.37K	1.000	42.38	1.009	2.37K	1.000	2.37K	0	42.09	1.002	2.37K	1.000	2.37K	0
	34.77	1.41K	39.36	*1.128*	1.75K	*1.221*	35.11	1.010	1.41K	1.000	1.47K	0	39.62	*1.136*	1.75K	*1.221*	1.70K	0
s100	0.81%	44	0.81%	1.000	44	1.000	0.81%	1.000	44	1.000	74	0	0.81%	1.000	45	1.007	81	0
	12.95%	37	12.95%	1.000	37	1.000	12.95%	1.000	37	1.000	38	0	12.95%	1.000	37	1.000	38	0
	0.43%	19	0.43%	1.000	19	1.000	0.43%	1.000	19	1.000	179	0	0.43%	1.000	19	1.000	179	0
s250r10	4933.43	13.71K	4941.72	1.002	13.71K	1.000	5019.52	1.017	13.71K	1.000	18.75K	0	5044.76	1.023	13.71K	1.000	18.75K	0
	3574.26	26.09K	3595.30	1.006	26.09K	1.000	3761.96	*1.052*	26.09K	1.000	31.55K	0	3745.21	1.048	26.09K	1.000	31.55K	0
	0.19%	43.36K	0.20%	1.000	42.98K	0.991	0.21%	1.000	38.10K	0.879	40.01K	0	0.21%	1.000	37.60K	0.867	39.60K	0
satellites2-40	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	2	0	∞	1.000	1	1.000	2	0
	∞	15	∞	1.000	16	1.009	∞	1.000	16	1.009	18	0	∞	1.000	16	1.009	18	0
	∞	2	∞	1.000	2	1.000	∞	1.000	2	1.000	1	0	∞	1.000	2	1.000	1	0

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Table B.1: Detailed computational results on Miplib 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	**T**	**N**	**T**	**T_Q**	**N**	**N_Q**	**T**	**T_Q**	**N**	**N_Q**	**#CFC**	**#CFA**	**T**	**T_Q**	**N**	**N_Q**	**#CFC**	**#CFA**
satellites2-60-fs	∞	49	∞	1.000	47	0.987	∞	1.000	48	0.993	80	0	∞	1.000	45	0.973	76	0
	∞	2	∞	1.000	2	1.000	∞	1.000	2	1.000	2	0	∞	1.000	2	1.000	2	0
	∞	2	∞	1.000	2	1.000	∞	1.000	2	1.000	9	0	∞	1.000	2	1.000	9	0
savsched1	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
sct2	0.03%	1.07M	0.03%	1.000	1.08M	1.004	0.03%	1.000	1.04M	0.965	825.09K	0	0.03%	1.000	1.03M	0.963	823.59K	0
	0.03%	594.65K	0.03%	1.000	597.21K	1.004	0.03%	1.000	582.16K	0.979	521.87K	0	0.03%	1.000	582.27K	0.979	522.00K	0
	0.03%	719.24K	0.03%	1.000	718.09K	0.998	0.03%	1.000	707.45K	0.984	651.17K	0	0.03%	1.000	707.10K	0.983	650.93K	0
seymour1	47.04	983	47.11	1.001	983	1.000	52.61	*1.116*	988	1.005	862	689	52.59	*1.116*	988	1.005	862	689
	46.40	1.10K	46.32	0.998	1.10K	1.000	51.06	*1.098*	1.20K	*1.084*	1.05K	904	50.92	*1.095*	1.20K	*1.084*	1.05K	904
	69.61	1.58K	69.86	1.004	1.58K	1.000	52.41	**0.756**	959	**0.628**	879	788	52.35	**0.756**	959	**0.628**	879	788
seymour	0.66%	255.43K	0.66%	1.000	256.07K	1.003	0.72%	1.000	258.28K	1.011	199.12K	17.16K	0.72%	1.000	254.63K	0.997	196.21K	16.07K
	0.64%	256.07K	0.67%	1.000	248.61K	0.971	0.71%	1.000	237.26K	0.927	172.77K	25.14K	0.71%	1.000	237.75K	0.928	173.11K	25.14K
	0.72%	232.03K	0.72%	1.000	231.39K	0.997	0.76%	1.000	244.86K	1.055	200.03K	25.53K	0.74%	1.000	244.86K	1.055	193.70K	24.07K
sing326	0.13%	6.44K	0.13%	1.000	6.37K	0.990	0.14%	1.000	5.97K	0.928	7.48K	0	0.13%	1.000	6.23K	0.968	7.78K	0
	0.13%	11.16K	0.13%	1.000	11.29K	1.012	0.13%	1.000	10.95K	0.982	14.26K	0	0.13%	1.000	10.79K	0.967	14.09K	0
	0.14%	8.48K	0.14%	1.000	8.46K	0.998	0.14%	1.000	8.31K	0.981	10.49K	0	0.14%	1.000	8.31K	0.981	10.49K	0
sing44	0.35%	3.00K	0.35%	1.000	2.94K	0.981	0.43%	1.000	2.84K	0.947	3.96K	0	0.43%	1.000	2.78K	0.930	3.88K	0
	0.42%	2.13K	0.42%	1.000	2.16K	1.015	0.42%	1.000	2.11K	0.991	2.99K	0	0.42%	1.000	2.10K	0.988	2.98K	0
	0.58%	3.42K	0.58%	1.000	3.46K	1.011	0.58%	1.000	3.42K	1.000	4.76K	0	0.58%	1.000	3.40K	0.996	4.74K	0
snp-02-004-104	0.00%	29.04K	0.00%	1.000	28.82K	0.993	0.00%	1.000	24.61K	0.848	17.41K	0	0.00%	1.000	24.61K	0.848	17.41K	0
	0.00%	21.68K	0.00%	1.000	21.90K	1.010	0.00%	1.000	20.28K	0.936	27.46K	0	0.00%	1.000	20.38K	0.940	27.61K	0
	0.00%	12.91K	0.00%	1.000	12.87K	0.997	0.00%	1.000	11.06K	0.858	12.85K	0	0.00%	1.000	10.99K	0.853	12.78K	0
sorrell3	16.51%	14.32K	16.51%	1.000	14.29K	0.998	16.52%	1.000	14.19K	0.992	9.09K	0	16.52%	1.000	14.22K	0.993	9.11K	0
	15.96%	16.01K	15.96%	1.000	15.97K	0.997	16.04%	1.000	15.71K	0.981	10.49K	0	16.04%	1.000	15.61K	0.975	10.43K	0
	16.75%	15.25K	16.83%	1.000	15.04K	0.986	16.76%	1.000	15.18K	0.995	10.02K	0	16.90%	1.000	14.98K	0.983	9.91K	0
sp150x300d	0.50	15	0.50	1.000	15	1.000	0.50	1.000	15	1.000	24	0	0.50	1.000	15	1.000	24	0
	0.50	50	0.50	1.000	50	1.000	0.50	1.000	50	1.000	56	0	0.50	1.000	50	1.000	56	0
	1.94	1.34K	1.98	1.014	1.34K	1.000	1.58	**0.878**	950	**0.728**	779	41	1.58	**0.878**	950	**0.728**	779	41
sp97ar	0.20%	95.59K	0.20%	1.000	95.56K	1.000	0.20%	1.000	95.14K	0.995	73.16K	0	0.20%	1.000	95.11K	0.995	73.14K	0
	0.23%	110.83K	0.23%	1.000	111.92K	1.010	0.24%	1.000	110.47K	0.997	81.23K	0	0.23%	1.000	110.73K	0.999	81.41K	0
	0.42%	141.37K	0.42%	1.000	141.97K	1.004	0.43%	1.000	139.44K	0.986	105.61K	0	0.43%	1.000	140.66K	0.995	106.52K	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
sp98ar	0.10%	90.77K	0.10%	1.000	90.51K	0.997	0.10%	1.000	90.60K	0.998	65.84K	0	0.10%	1.000	90.58K	0.998	65.84K	0
	0.16%	124.22K	0.18%	1.000	123.75K	0.996	0.18%	1.000	122.99K	0.990	97.44K	0	0.18%	1.000	123.11K	0.991	97.52K	0
	0.14%	120.68K	0.14%	1.000	120.31K	0.997	0.15%	1.000	119.16K	0.987	93.50K	0	0.15%	1.000	119.39K	0.989	93.65K	0
splice1k1	306.43%	726	302.62%	1.000	1.36K	1.769	306.43%	1.000	722	0.995	629	0	302.62%	1.000	1.36K	1.769	1.06K	0
	308.00%	480	700.57%	1.000	354	0.783	308.00%	1.000	481	1.002	496	0	700.57%	1.000	355	0.784	502	0
	306.67%	494	304.89%	1.000	680	1.313	306.67%	1.000	496	1.003	482	0	304.89%	1.000	680	1.313	538	0
square41	80.82%	51	80.82%	1.000	52	1.007	80.82%	1.000	52	1.007	88	0	80.82%	1.000	52	1.007	88	0
	90.41%	37	90.41%	1.000	38	1.007	90.41%	1.000	37	1.000	66	0	90.41%	1.000	36	0.993	65	0
	125.73%	35	125.73%	1.000	35	1.000	125.73%	1.000	35	1.000	58	0	125.73%	1.000	35	1.000	58	0
square47	127.88%	17	127.88%	1.000	17	1.000	127.88%	1.000	17	1.000	22	0	127.88%	1.000	17	1.000	22	0
	230.06%	11	230.06%	1.000	11	1.000	230.06%	1.000	11	1.000	11	0	230.06%	1.000	11	1.000	11	0
	82.48%	9	82.48%	1.000	9	1.000	82.48%	1.000	9	1.000	11	0	82.48%	1.000	9	1.000	11	0
supportcase10	448.45%	1	448.36%	1.000	1	1.000	448.45%	1.000	1	1.000	0	0	448.45%	1.000	1	1.000	0	0
	431.09%	1	431.09%	1.000	1	1.000	431.09%	1.000	1	1.000	0	0	431.09%	1.000	1	1.000	0	0
	190.72%	11	423.30%	1.000	7	0.964	423.30%	1.000	7	0.964	6	0	423.30%	1.000	7	0.964	6	0
supportcase12	1.21%	4.91K	1.21%	1.000	4.91K	1.000	1.21%	1.000	4.87K	0.992	4.44K	0	1.21%	1.000	4.89K	0.995	4.46K	0
	0.84%	9.35K	0.84%	1.000	9.34K	0.999	0.84%	1.000	9.25K	0.989	8.49K	0	0.84%	1.000	9.24K	0.988	8.49K	0
	0.71%	5.50K	0.71%	1.000	7.38K	1.336	0.71%	1.000	5.43K	0.989	5.20K	0	0.71%	1.000	7.31K	1.325	6.77K	0
supportcase18	3.84%	401.37K	3.84%	1.000	400.73K	0.998	3.84%	1.000	386.26K	0.962	328.28K	0	3.84%	1.000	386.30K	0.962	328.31K	0
	3.84%	228.84K	3.84%	1.000	229.02K	1.001	3.84%	1.000	222.59K	0.973	191.93K	0	3.84%	1.000	222.53K	0.972	191.87K	0
	5.96%	259.80K	5.96%	1.000	258.61K	0.995	5.96%	1.000	248.17K	0.955	232.87K	0	5.96%	1.000	249.57K	0.961	234.22K	0
supportcase19	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000	0	0	∞	1.000	1	1.000	0	0
supportcase22	∞	14	∞	1.000	14	1.000	∞	1.000	14	1.000	13	0	∞	1.000	14	1.000	13	0
	∞	13	∞	1.000	13	1.000	∞	1.000	13	1.000	13	0	∞	1.000	13	1.000	12	0
	∞	11	∞	1.000	11	1.000	∞	1.000	11	1.000	10	0	∞	1.000	11	1.000	10	0
supportcase26	9.73%	7.65M	9.88%	1.000	7.80M	1.019	11.62%	1.000	6.83M	0.893	4.57M	4.19M	11.50%	1.000	7.01M	0.916	4.73M	4.36M
	8.74%	7.86M	8.92%	1.000	7.90M	1.005	9.96%	1.000	7.60M	0.967	4.90M	4.62M	9.82%	1.000	7.86M	1.000	5.05M	4.79M
	8.87%	8.71M	9.88%	1.000	8.31M	0.954	11.09%	1.000	7.01M	0.804	4.60M	4.26M	11.09%	1.000	6.95M	0.797	4.56M	4.23M
supportcase33	32.27%	4.21K	32.27%	1.000	4.15K	0.987	32.27%	1.000	4.14K	0.985	16.38K	0	32.27%	1.000	4.14K	0.985	16.38K	0
	3153.03	16.10K	3187.18	1.011	16.02K	0.995	3180.82	1.009	16.10K	1.000	26.03K	0	3236.17	1.026	16.02K	0.995	26.05K	0
	879.58	3.90K	888.75	1.010	3.90K	1.000	888.85	1.011	3.90K	1.000	6.32K	0	890.06	1.012	3.90K	1.000	6.32K	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
supportcase40	1215.22	11.89K	1205.32	0.992	11.89K	1.000	1214.16	0.999	11.89K	1.000	7.96K	0	1216.25	1.001	11.89K	1.000	7.96K	0
	975.94	10.11K	980.53	1.005	10.11K	1.000	983.91	1.008	10.11K	1.000	6.78K	0	984.87	1.009	10.11K	1.000	6.78K	0
	1096.37	11.00K	1097.56	1.001	11.00K	1.000	1102.20	1.005	11.00K	1.000	7.66K	0	1101.40	1.005	11.00K	1.000	7.66K	0
supportcase42	0.13%	401.93K	0.13%	1.000	400.69K	0.997	0.13%	1.000	364.91K	0.908	364.95K	0	0.13%	1.000	363.99K	0.906	363.79K	0
	1896.26	76.15K	1896.90	1.000	76.15K	1.000	2057.68	*1.085*	76.15K	1.000	86.18K	0	2047.15	*1.080*	76.15K	1.000	86.18K	0
	0.24%	417.67K	0.25%	1.000	372.77K	0.893	0.24%	1.000	361.05K	0.864	361.10K	0	0.25%	1.000	321.56K	0.770	349.05K	0
supportcase6	9.35%	15.75K	9.35%	1.000	15.60K	0.990	9.53%	1.000	14.48K	0.920	10.81K	0	9.53%	1.000	14.37K	0.913	10.74K	0
	9.93%	20.66K	9.93%	1.000	21.13K	1.022	9.93%	1.000	19.82K	0.959	14.93K	0	9.93%	1.000	19.96K	0.966	15.03K	0
	9.29%	19.79K	9.32%	1.000	19.44K	0.983	9.32%	1.000	18.75K	0.948	14.18K	0	9.32%	1.000	18.71K	0.946	14.15K	0
supportcase7	150.41	49	150.89	1.003	49	1.000	150.76	1.002	49	1.000	49	0	150.88	1.003	49	1.000	49	0
	132.54	13	133.59	1.008	13	1.000	133.17	1.005	13	1.000	27	0	132.71	1.001	13	1.000	27	0
	165.79	17	165.77	1.000	17	1.000	166.21	1.003	17	1.000	34	0	166.24	1.003	17	1.000	34	0
swath1	10.26	206	10.25	0.999	206	1.000	10.51	1.022	206	1.000	497	0	10.52	1.023	206	1.000	497	0
	17.20	376	17.29	1.005	376	1.000	17.52	1.018	376	1.000	780	0	17.58	1.021	376	1.000	780	0
	12.63	364	12.69	1.004	364	1.000	12.86	1.017	364	1.000	612	0	12.94	1.023	364	1.000	612	0
swath3	151.32	25.41K	151.14	0.999	25.41K	1.000	160.18	*1.058*	25.41K	1.000	20.34K	0	160.49	*1.060*	25.41K	1.000	20.34K	0
	88.57	11.04K	88.94	1.004	11.04K	1.000	92.15	1.040	11.04K	1.000	9.35K	0	92.75	1.047	11.04K	1.000	9.35K	0
	271.46	54.20K	271.04	0.998	54.20K	1.000	286.63	*1.056*	54.20K	1.000	40.02K	0	286.35	*1.055*	54.20K	1.000	40.02K	0
tbfp-network	1478.38	143	1477.49	0.999	143	1.000	1482.41	1.003	143	1.000	186	0	1478.12	1.000	143	1.000	186	0
	3382.06	352	3380.29	0.999	352	1.000	3368.60	0.996	352	1.000	486	0	3391.07	1.003	352	1.000	486	0
	1518.13	135	1520.73	1.002	135	1.000	1526.49	1.006	135	1.000	164	0	1522.70	1.003	135	1.000	164	0
thor50dday	15.85%	25	15.85%	1.000	26	1.008	15.85%	1.000	25	1.000	237	0	15.85%	1.000	26	1.008	239	0
	13.46%	4	13.43%	1.000	4	1.000	13.46%	1.000	4	1.000	211	0	13.43%	1.000	4	1.000	212	0
	12.72%	36	12.72%	1.000	34	0.985	12.72%	1.000	34	0.985	190	0	12.72%	1.000	34	0.985	190	0
timtab1	63.38	54.59K	63.92	1.008	54.59K	1.000	48.11	**0.763**	32.42K	**0.595**	27.42K	16.76K	54.14	**0.856**	41.21K	**0.755**	33.94K	19.31K
	52.87	40.73K	53.41	1.010	40.73K	1.000	50.99	0.965	33.07K	**0.812**	30.07K	24.38K	50.87	0.963	33.07K	**0.812**	30.07K	24.38K
	49.35	32.86K	49.18	0.997	32.86K	1.000	51.70	1.047	33.39K	1.016	27.93K	15.32K	52.31	*1.059*	33.92K	1.032	28.71K	15.74K
tr12-30	838.84	511.03K	838.16	0.999	511.03K	1.000	1205.60	*1.437*	563.03K	*1.102*	368.32K	368.15K	1221.75	*1.456*	563.75K	*1.103*	370.15K	369.61K
	486.16	233.26K	482.97	0.993	231.41K	0.992	804.07	*1.653*	297.32K	*1.275*	294.63K	294.57K	807.56	*1.660*	297.32K	*1.275*	294.63K	294.57K
	665.75	378.62K	659.89	0.991	378.62K	1.000	696.42	1.046	273.26K	**0.722**	269.24K	269.12K	698.87	1.050	273.26K	**0.722**	269.24K	269.12K
traininstance2	$\geq$ 1000%	51.30K	$\geq$ 1000%	1.000	51.14K	0.997	$\geq$ 1000%	1.000	51.22K	0.998	232.54K	0	$\geq$ 1000%	1.000	51.04K	0.995	227.40K	0
	∞	59.27K	∞	1.000	59.48K	1.004	∞	1.000	58.00K	0.979	216.42K	0	∞	1.000	58.21K	0.982	216.75K	0
	$\geq$ 1000%	67.49K	$\geq$ 1000%	1.000	67.20K	0.996	$\geq$ 1000%	1.000	66.37K	0.983	182.51K	0	$\geq$ 1000%	1.000	65.96K	0.977	181.47K	0

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Table B.1: Detailed computational results on MIPLIB 2017 benchmark with and without solution and conflict-free learning.

	default		sollearning				conffree						combined					
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	#CFC	#CFA	T	T_Q	N	N_Q	#CFC	#CFA
traininstance6	625.38%	324.96K	625.38%	1.000	326.52K	1.005	636.72%	1.000	317.39K	0.977	618.16K	0	636.72%	1.000	319.47K	0.983	619.82K	0
	584.78%	344.42K	584.78%	1.000	345.03K	1.002	600.00%	1.000	338.75K	0.984	374.77K	0	584.78%	1.000	341.60K	0.992	376.67K	0
	$\geq$ 1000%	303.92K	$\geq$ 1000%	1.000	331.85K	1.092	$\geq$ 1000%	1.000	303.20K	0.998	404.02K	0	$\geq$ 1000%	1.000	333.23K	1.096	368.32K	0
trento1	0.07%	67.60K	0.09%	1.000	70.09K	1.037	0.09%	1.000	45.27K	0.670	54.55K	0	0.09%	1.000	44.84K	0.664	54.04K	0
	0.08%	71.75K	0.08%	1.000	65.77K	0.917	0.08%	1.000	61.22K	0.854	70.02K	0	0.08%	1.000	62.59K	0.872	70.47K	0
	0.08%	38.35K	0.08%	1.000	38.10K	0.994	0.08%	1.000	37.84K	0.987	42.82K	0	0.08%	1.000	37.86K	0.987	42.84K	0
triptim1	245.37	1	244.18	0.995	1	1.000	243.62	0.993	1	1.000	3	0	245.54	1.001	1	1.000	3	0
	268.76	1	270.74	1.007	1	1.000	268.06	0.997	1	1.000	2	0	276.25	1.028	1	1.000	2	0
	1256.99	6	1241.07	0.987	6	1.000	1242.25	0.988	6	1.000	8	0	1242.14	0.988	6	1.000	8	0
uccase12	0.00%	79.84K	0.00%	1.000	80.04K	1.003	0.00%	1.000	72.59K	0.909	72.75K	0	0.00%	1.000	72.63K	0.910	72.79K	0
	0.00%	69.98K	0.00%	1.000	70.19K	1.003	0.00%	1.000	64.51K	0.922	67.34K	0	0.00%	1.000	64.51K	0.922	67.34K	0
	0.00%	81.83K	0.00%	1.000	81.47K	0.996	0.00%	1.000	70.99K	0.868	71.02K	0	0.00%	1.000	71.58K	0.875	71.61K	0
uccase9	2.37%	915	2.37%	1.000	913	0.998	2.37%	1.000	913	0.998	1.09K	0	2.37%	1.000	908	0.993	1.07K	0
	4.97%	664	4.97%	1.000	666	1.003	4.97%	1.000	664	1.000	677	0	4.97%	1.000	664	1.000	677	0
	2.07%	876	2.07%	1.000	875	0.999	2.07%	1.000	874	0.998	971	0	2.07%	1.000	885	1.009	986	0
uct-subprob	1143.76	40.00K	1227.44	*1.073*	41.38K	1.034	1141.47	0.998	40.00K	1.000	36.49K	0	1233.26	*1.078*	41.38K	1.034	37.47K	0
	2683.37	87.05K	2576.49	0.960	84.85K	0.975	2704.06	1.008	87.05K	1.000	79.07K	0	2596.38	0.968	84.85K	0.975	78.38K	0
	1145.19	33.16K	1114.15	0.973	33.16K	1.000	1145.71	1.000	33.16K	1.000	29.60K	0	1113.96	0.973	33.16K	1.000	29.49K	0
unitcal_7	254.54	7	255.16	1.002	7	1.000	254.01	0.998	7	1.000	32	0	254.09	0.998	7	1.000	32	0
	273.72	69	272.69	0.996	69	1.000	266.45	0.974	30	**0.769**	142	95	267.34	0.977	30	**0.769**	142	95
	282.92	10	283.85	1.003	10	1.000	283.99	1.004	10	1.000	58	1	284.31	1.005	10	1.000	58	1
var-smallemery-m6j6	0.62%	630.54K	0.60%	1.000	634.13K	1.006	0.66%	1.000	621.09K	0.985	353.05K	0	0.65%	1.000	622.69K	0.988	353.35K	0
	0.96%	622.34K	0.95%	1.000	626.49K	1.007	0.98%	1.000	609.40K	0.979	381.41K	0	0.97%	1.000	614.03K	0.987	383.39K	0
	0.98%	631.01K	0.98%	1.000	632.10K	1.002	1.00%	1.000	616.95K	0.978	394.35K	0	1.00%	1.000	617.34K	0.978	394.52K	0
wachplan	1859.64	71.81K	1858.76	1.000	71.81K	1.000	1858.75	1.000	71.81K	1.000	37.62K	0	1861.35	1.001	71.81K	1.000	37.62K	0
	3039.07	266.36K	3054.59	1.005	266.36K	1.000	3059.00	1.007	266.36K	1.000	136.74K	0	3054.32	1.005	266.36K	1.000	136.74K	0
	2736.94	222.61K	2738.74	1.001	222.61K	1.000	2752.93	1.006	222.61K	1.000	113.99K	0	2748.52	1.004	222.61K	1.000	113.99K	0

Appendix C

Local Rapid Learning for Integer Programmms

This chapter presents detailed computational results of the experiments discussed in Chapter 5.

- Table C.1 illustrates the individual impact with respect to solving time and nodes of all six criteria individually when running Rapid Learning locally, running Rapid Learning locally without any criterion (`nochecks`), and applying Rapid Learning to the root node only (`onlyroot`). Baseline is SCIP without Rapid Learning at all (`default`).
- Table C.2 illustrates the individual impact with respect to solving time and nodes of criterion LP degeneracy (`degeneracy`) compared to `onlyroot`, `nochecks`, and `default`.
- Table C.3 illustrates the impact of three different combinations of criteria: LP degeneracy and portion of infeasible leave nodes (`degeneracy` + `leaves`), portion of infeasible leave nodes and local zero objective function (`leaves` + `obj`), and all six criteria simultaneously (`all6criterion`).
- Table C.4 illustrates the individual impact with respect to solving time and nodes of transferring variable bound reductions (`variablebounds`), conflict constraints (`conflicts`), inference information (`infervals`), and primal solution (`primsols`) found during the CP search back to the MIP search.

Table C.1: Computational results on MMM-IP: Impact of criteria. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	default		degeneracy		dualbound		leaves		obj		nsols		sblps		nochecks		onlyroot	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
10teams	2.14	1	*1.277*	1.000	0.990	1.000	0.994	1.000	0.990	1.000	*1.271*	1.000	0.994	1.000	*1.248*	1.000	*1.258*	1.000
	20.00	1369	**0.241**	**0.072**	*1.290*	**0.687**	*1.236*	1.001	0.995	1.000	**0.244**	**0.072**	0.963	**0.303**	**0.245**	**0.072**	**0.246**	**0.072**
	15.57	287	*1.607*	*2.729*	*2.062*	*4.067*	0.998	1.000	1.006	1.000	*1.308*	*2.729*	*2.080*	*4.238*	*1.341*	**0.829**	**0.672**	**0.323**
	4.16	5	*2.721*	*1.219*	1.000	1.000	1.006	1.000	0.996	1.000	*2.713*	*1.219*	1.004	1.000	*2.709*	*1.219*	*2.329*	*1.219*
	4.94	5	**0.909**	1.000	1.000	1.000	1.002	1.000	1.007	1.000	**0.909**	1.000	0.995	1.000	**0.912**	1.000	**0.914**	1.000
30n20b8	314.13	195	**0.605**	**0.553**	1.002	1.000	1.001	1.000	0.990	1.000	**0.289**	**0.346**	0.999	1.000	**0.285**	**0.346**	**0.289**	**0.346**
	157.33	71	**0.712**	**0.596**	0.999	1.000	0.998	1.000	0.995	1.000	**0.810**	**0.596**	0.999	1.000	**0.789**	**0.596**	**0.852**	**0.596**
	87.25	4	1.001	1.000	1.000	1.000	1.003	1.000	0.998	1.000	*1.191*	1.000	0.997	1.000	*1.180*	0.981	*1.188*	1.000
	213.06	102	*1.208*	*1.312*	0.996	1.000	0.991	1.000	0.978	0.950	*1.251*	**0.896**	0.993	1.000	1.047	**0.782**	*1.251*	**0.896**
	470.09	290	**0.811**	**0.723**	0.998	1.000	1.003	1.000	0.998	1.000	**0.238**	**0.423**	0.996	1.000	**0.241**	**0.421**	**0.238**	**0.423**
acc-tight5	125.35	172	*1.114*	*1.171*	**0.387**	**0.295**	**0.423**	**0.302**	1.011	0.965	**0.651**	**0.735**	0.991	1.000	*1.087*	*1.171*	*1.115*	*1.622*
	84.38	98	*1.310*	*2.072*	*1.512*	*1.286*	**0.448**	**0.326**	**0.856**	**0.551**	*1.786*	*2.650*	0.991	1.000	*1.792*	*2.650*	**0.721**	0.952
	50.45	480	0.973	**0.929**	*2.656*	*2.631*	*1.753*	*1.966*	1.022	0.993	0.973	**0.929**	1.002	1.000	0.974	**0.929**	*3.299*	*6.017*
	85.88	87	**0.340**	**0.189**	*1.590*	*1.794*	**0.401**	**0.290**	**0.420**	**0.274**	**0.339**	**0.189**	1.000	1.000	**0.340**	**0.189**	*1.464*	*1.891*
	73.38	864	**0.417**	**0.161**	*1.440*	*1.091*	*2.064*	*1.326*	*1.488*	*1.309*	**0.417**	**0.161**	0.996	1.000	**0.419**	**0.161**	*1.256*	*1.088*
air03	1.70	1	1.011	1.000	1.015	1.000	1.015	1.000	1.015	1.000	1.004	1.000	1.007	1.000	*6.433*	1.000	*6.515*	1.000
	1.71	1	1.004	1.000	1.004	1.000	1.011	1.000	1.004	1.000	0.996	1.000	1.007	1.000	*6.590*	1.000	*6.472*	1.000
	1.74	1	0.993	1.000	1.011	1.000	1.004	1.000	0.989	1.000	1.000	1.000	0.985	1.000	*6.365*	1.000	*6.372*	1.000
	1.75	1	1.000	1.000	0.996	1.000	1.000	1.000	0.996	1.000	1.000	1.000	1.000	1.000	*6.378*	1.000	*6.335*	1.000
	1.75	1	0.996	1.000	0.993	1.000	0.985	1.000	0.985	1.000	0.993	1.000	1.004	1.000	*6.491*	1.000	*6.378*	1.000
air04	49.46	110	1.003	1.000	1.007	1.000	1.008	1.000	1.005	1.000	1.003	1.000	1.006	1.000	0.978	**0.776**	**0.911**	**0.652**
	36.09	39	1.008	1.000	1.003	1.000	1.004	1.000	0.996	1.000	1.000	1.000	1.002	1.000	*1.172*	*1.144*	*1.112*	*1.158*
	52.88	118	1.005	1.000	1.000	1.000	1.002	1.000	0.999	1.000	0.997	1.000	0.990	1.000	0.993	**0.665**	**0.949**	**0.665**
	36.56	31	1.014	1.000	1.007	1.000	1.010	1.000	1.001	1.000	0.995	1.000	1.010	1.000	*1.552*	*1.481*	*1.735*	*3.061*
	48.35	122	1.006	1.000	1.002	1.000	1.004	1.000	1.001	1.000	1.004	1.000	1.003	1.000	**0.803**	**0.500**	**0.801**	**0.500**
air05	24.82	189	0.990	1.000	0.996	1.000	0.999	1.000	1.006	1.000	1.003	1.000	0.990	1.000	*2.135*	*1.388*	*1.270*	*1.547*
	26.54	239	1.004	1.000	1.005	1.000	1.001	1.000	1.008	1.000	1.001	1.000	1.003	1.000	*3.006*	*1.714*	*1.275*	*1.419*
	31.37	438	0.992	1.000	0.992	1.000	0.997	1.000	0.996	1.000	0.994	1.000	0.997	1.000	*1.869*	**0.690**	*1.132*	**0.946**
	27.36	283	1.007	1.000	1.006	1.000	1.006	1.000	1.007	1.000	1.006	1.000	0.996	1.000	*1.679*	*1.222*	*1.175*	*1.204*
	27.14	279	1.003	1.000	1.003	1.000	1.002	1.000	1.002	1.000	1.004	1.000	0.996	1.000	*2.084*	*1.343*	*1.128*	**0.934**
blend2	0.69	714	1.041	1.000	1.041	1.000	1.036	1.000	1.047	1.000	1.041	1.000	1.047	1.000	1.041	1.000	1.041	1.000
	1.08	973	0.986	1.000	1.005	1.000	0.971	1.000	1.019	1.000	1.005	1.000	0.971	1.000	1.010	1.000	0.986	1.000
	1.05	912	1.005	1.000	0.995	1.000	0.990	1.000	1.000	1.000	0.985	1.000	1.000	1.000	1.000	1.000	0.995	1.000
	0.67	543	0.994	1.000	1.006	1.000	1.012	1.000	1.030	1.000	1.000	1.000	1.012	1.000	1.012	1.000	1.018	1.000
	0.66	709	1.030	1.000	1.018	1.000	1.018	1.000	1.006	1.000	1.036	1.000	1.042	1.000	1.024	1.000	1.030	1.000

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Table C.1: Computational results on MMM-IP: Impact of criteria.

	default		degeneracy		dualbound		leaves		obj		nsols		sblps		nochecks		onlyroot	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
bley_xl1	164.49	1	0.997	1.000	1.002	1.000	0.998	1.000	1.000	1.000	1.008	1.000	0.996	1.000	0.997	1.000	1.003	1.000
	187.04	3	1.012	*1.146*	1.007	1.000	1.005	1.000	1.002	1.000	1.005	1.000	1.003	1.000	**0.906**	0.981	**0.907**	0.981
	182.51	13	**0.892**	**0.903**	1.012	1.000	1.015	1.000	1.012	1.000	1.013	1.000	1.001	0.956	**0.901**	**0.903**	**0.898**	**0.903**
	133.90	1	1.006	1.000	1.008	1.000	1.003	1.000	1.005	1.000	1.005	1.000	1.011	1.000	0.982	1.000	*1.118*	1.000
	135.56	1	1.006	1.000	1.006	1.000	1.001	1.000	1.000	1.000	1.005	1.000	1.008	1.000	1.014	1.000	1.023	1.000
bnatt350	378.09	89	**0.052**	**0.030**	**0.431**	**0.301**	**0.107**	**0.054**	*3.061*	*2.782*	**0.053**	**0.030**	**0.121**	**0.041**	**0.052**	**0.030**	*2.109*	*2.434*
	521.76	326	**0.033**	**0.022**	**0.276**	**0.183**	**0.144**	**0.084**	*1.081*	*1.382*	**0.033**	**0.022**	1.011	*1.431*	**0.033**	**0.022**	**0.487**	**0.420**
	397.10	160	**0.048**	**0.026**	**0.119**	**0.057**	**0.131**	**0.063**	**0.610**	**0.445**	**0.048**	**0.026**	**0.301**	**0.229**	**0.048**	**0.026**	**0.889**	**0.846**
	155.46	4028	**0.109**	**0.067**	**0.262**	**0.129**	*2.325*	*2.588*	*1.524*	*1.482*	**0.109**	**0.067**	**0.389**	**0.127**	**0.110**	**0.067**	*4.491*	*3.610*
	994.16	2528	**0.044**	**0.021**	**0.575**	**0.724**	**0.329**	**0.259**	**0.713**	**0.670**	**0.044**	**0.021**	**0.156**	**0.076**	**0.045**	**0.021**	**0.317**	**0.315**
cap6000	2.69	1830	1.003	1.000	1.019	1.000	1.003	1.000	1.019	1.000	1.016	1.000	0.989	1.000	*1.412*	*1.131*	*1.098*	**0.866**
	2.67	1837	0.986	1.000	0.984	1.000	0.989	1.000	0.986	1.000	0.975	1.000	1.003	1.000	*1.455*	*1.256*	*1.155*	*1.142*
	2.61	1959	0.992	1.000	1.000	1.000	0.997	1.000	1.006	1.000	0.997	1.000	0.992	1.000	*1.280*	0.982	*1.150*	*1.066*
	3.17	1924	1.007	1.000	0.990	1.000	1.007	1.000	0.993	1.000	0.995	1.000	0.995	1.000	*1.422*	*1.166*	*1.086*	**0.894**
	2.82	1762	1.008	1.000	1.008	1.000	0.995	1.000	0.987	1.000	0.995	1.000	1.008	1.000	*1.387*	*1.325*	*1.157*	*1.258*
cov1075	3600.00	1445091	0.989	*1.189*	1.000	0.981	1.000	0.996	1.000	1.004	1.000	0.991	1.000	0.985	1.000	**0.314**	0.961	*1.189*
	3600.00	1787171	1.000	0.975	1.000	0.982	1.000	0.998	1.000	1.004	1.000	1.003	1.000	0.989	1.000	**0.303**	1.000	0.989
	3600.00	1528146	1.000	*1.198*	1.000	0.986	1.000	0.998	1.000	0.997	1.000	0.999	1.000	0.956	1.000	**0.373**	1.000	*1.210*
	3600.00	1808088	1.000	0.985	1.000	0.995	1.000	1.006	1.000	1.002	1.000	1.006	1.000	0.974	1.000	**0.250**	0.997	0.995
	3600.00	1201194	1.000	*1.508*	1.000	0.986	1.000	0.997	1.000	0.999	1.000	1.000	1.000	**0.898**	1.000	**0.460**	0.979	*1.514*
csched010	3600.00	228369	1.000	1.003	1.000	1.001	1.000	0.963	1.000	0.999	**0.758**	**0.644**	1.000	1.001	1.000	**0.571**	**0.907**	**0.925**
	3600.00	175223	1.000	1.001	1.000	1.001	1.000	**0.864**	1.000	1.000	0.972	1.038	1.000	0.999	1.000	**0.756**	**0.850**	1.037
	2891.69	214060	1.000	1.000	0.951	**0.941**	*1.147*	*1.206*	0.997	1.000	*1.245*	*1.145*	1.002	1.000	*1.245*	**0.689**	*1.245*	*1.280*
	3600.00	195746	1.000	0.998	1.000	0.996	0.988	**0.820**	1.000	0.998	1.000	0.960	1.000	0.997	1.000	**0.578**	1.000	1.028
	3168.37	226703	1.001	1.000	0.999	1.000	*1.136*	*1.303*	1.000	1.000	*1.136*	*1.352*	1.001	1.000	*1.136*	**0.682**	*1.136*	*1.307*
eil33-2	69.44	583	1.003	1.000	1.034	1.000	1.005	1.000	1.034	1.000	1.031	1.000	1.008	1.000	*1.772*	**0.909**	*1.094*	**0.909**
	81.92	739	1.007	1.000	1.007	1.000	1.010	1.000	0.997	1.000	1.009	1.000	1.007	1.000	*1.671*	**0.852**	1.028	**0.852**
	84.87	847	0.989	1.000	0.999	1.000	1.001	1.000	1.001	1.000	1.008	1.000	1.002	1.000	*1.904*	**0.852**	*1.195*	**0.852**
	73.60	543	0.988	1.000	1.007	1.000	1.000	1.000	1.001	1.000	1.010	1.000	1.003	1.000	*2.006*	*1.509*	*1.260*	*2.728*
	70.01	583	0.987	1.000	1.007	1.000	1.002	1.000	1.002	1.000	1.007	1.000	1.003	1.000	*2.176*	*1.433*	*1.602*	*1.416*
eilB101	378.99	10582	0.998	1.000	1.021	1.000	1.002	1.000	1.023	1.000	0.999	1.000	1.009	1.000	*1.083*	**0.724**	**0.705**	**0.724**
	365.27	8427	0.984	1.000	0.995	1.000	0.993	1.000	0.999	1.000	1.005	1.000	0.997	1.000	*1.391*	*1.150*	**0.916**	*1.050*
	401.63	9358	0.995	1.000	1.000	1.000	0.998	1.000	0.993	1.000	1.008	1.000	0.997	1.000	*1.147*	**0.780**	**0.819**	**0.780**
	397.46	11465	0.996	1.000	0.999	1.000	0.998	1.000	0.999	1.000	1.002	1.000	0.995	1.000	*1.304*	1.025	**0.905**	1.025
	365.79	10006	0.989	1.000	0.998	1.000	0.989	1.000	0.994	1.000	0.996	1.000	1.001	1.000	*1.201*	**0.894**	**0.818**	**0.894**
enigma	0.50	809	1.000	**0.825**	1.020	**0.716**	1.000	1.000	1.000	0.998	1.000	**0.542**	*1.140*	**0.686**	1.000	**0.542**	1.000	**0.856**
	0.50	449	1.000	**0.497**	1.000	**0.814**	1.000	1.000	1.000	1.000	1.000	**0.470**	1.000	**0.778**	1.000	**0.470**	1.000	*1.616*

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Table C.1: Computational results on MMM-IP: Impact of criteria.

Instance	default		degeneracy		dualbound		leaves		obj		nsols		sblps		nochecks		onlyroot	
	T	**N**	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	0.50	541	1.000	**0.254**	1.000	**0.510**	1.000	1.000	1.000	0.977	1.000	**0.237**	*1.060*	**0.721**	1.000	**0.237**	1.000	**0.665**
	0.50	679	*1.073*	**0.537**	1.000	**0.397**	1.000	1.000	1.000	1.000	1.000	**0.151**	*1.133*	*1.113*	1.000	**0.151**	1.000	**0.244**
	0.50	445	1.020	**0.543**	1.000	**0.833**	1.000	1.000	1.000	1.006	1.000	**0.543**	1.000	**0.806**	1.013	**0.543**	1.000	*1.675*
enlight13	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
enlight14	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
fiber	1.00	2	1.010	1.000	1.010	1.000	0.990	1.000	1.005	1.000	1.000	1.000	1.000	1.000	*1.160*	1.010	*1.075*	1.010
	1.42	4	0.988	1.000	1.004	1.000	0.988	1.000	1.000	1.000	0.992	1.000	1.008	1.000	*1.384*	*1.240*	**0.938**	0.990
	1.74	4	1.007	1.000	0.993	1.000	0.996	1.000	0.996	1.000	0.978	1.000	0.982	1.000	*1.401*	1.010	**0.949**	0.990
	1.53	4	1.008	1.000	1.000	1.000	0.996	1.000	0.996	1.000	0.988	1.000	1.000	1.000	*1.194*	0.990	1.024	1.000
	1.00	3	1.000	1.000	1.005	1.000	1.005	1.000	1.000	1.000	0.995	1.000	1.005	1.000	*1.080*	0.990	1.030	0.990
flugpl	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
gt2	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
harp2	691.56	1491878	1.005	1.000	1.001	1.000	1.001	1.000	1.007	1.000	1.000	1.000	1.003	1.000	*5.200*	*5.260*	*4.215*	*4.834*
	1159.66	2857677	1.004	1.000	0.998	1.000	0.994	1.000	0.998	1.000	0.993	1.000	0.994	1.000	**0.410**	**0.228**	*2.318*	*2.253*
	336.73	595854	0.992	1.000	1.007	1.000	1.007	1.000	1.005	1.000	1.002	1.000	0.999	1.000	*1.604*	*1.232*	*1.348*	*1.300*
	937.54	2046181	0.997	1.000	0.987	1.000	0.992	1.000	1.000	1.000	0.997	1.000	0.999	1.000	**0.506**	**0.321**	*1.065*	*1.052*
	425.68	923780	1.018	1.000	1.010	1.000	1.009	1.000	1.013	1.000	1.014	1.000	1.021	1.000	*2.779*	*2.192*	*7.701*	*8.726*
iis-100-0-cov	629.92	103302	0.993	1.000	0.993	1.000	1.014	1.000	0.991	1.000	0.997	1.000	0.992	1.000	0.999	0.999	0.965	0.999
	545.20	92393	0.999	1.000	0.997	1.000	1.001	1.000	1.002	1.000	0.996	1.000	0.998	1.000	*1.128*	1.046	*1.053*	1.046
	520.78	81639	0.999	1.000	1.000	1.000	1.002	1.000	1.001	1.000	1.000	1.000	0.997	1.000	*1.151*	*1.128*	*1.097*	*1.128*
	506.53	84800	1.002	1.000	0.997	1.000	0.995	1.000	0.996	1.000	0.998	1.000	0.998	1.000	*1.117*	*1.080*	*1.077*	*1.080*

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Table C.1: Computational results on MMM-IP: Impact of criteria.

	default		degeneracy		dualbound		leaves		obj		nsols		sblps		nochecks		onlyroot	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	544.56	92313	0.996	1.000	0.999	1.000	1.004	1.000	1.001	1.000	1.002	1.000	0.998	1.000	*1.089*	*1.052*	0.990	*1.052*
iis-bupa-cov	1915.72	157619	1.001	1.000	1.009	1.000	1.002	1.000	1.000	1.000	1.007	1.000	1.003	1.000	*1.704*	*1.376*	*1.344*	*1.376*
	1944.83	164079	0.997	1.000	0.995	1.000	0.997	1.000	0.996	1.000	0.994	1.000	0.995	1.000	*1.259*	*1.099*	*1.117*	*1.099*
	1881.83	156888	0.998	1.000	0.999	1.000	0.993	1.000	0.998	1.000	0.996	1.000	0.996	1.000	*1.189*	*1.093*	*1.081*	*1.093*
	1959.19	161969	0.989	1.000	1.005	1.000	0.996	1.000	0.996	1.000	0.994	1.000	0.998	1.000	*1.398*	*1.234*	*1.193*	*1.234*
	1820.52	158284	0.990	1.000	0.997	1.000	0.994	1.000	0.995	1.000	0.995	1.000	0.994	1.000	*1.378*	*1.219*	*1.241*	*1.219*
iis-pima-cov	293.79	4824	0.995	1.000	0.997	1.000	1.002	1.000	1.002	1.000	0.993	1.000	0.997	1.000	*1.072*	*1.109*	1.016	*1.109*
	437.19	12189	0.995	1.000	0.997	1.000	0.994	1.000	1.001	1.000	1.003	1.000	0.999	1.000	**0.746**	**0.445**	**0.712**	**0.445**
	246.99	4668	1.000	1.000	1.001	1.000	1.004	1.000	1.006	1.000	1.005	1.000	1.004	1.000	*1.326*	*1.583*	*1.214*	*1.583*
	284.88	6607	1.002	1.000	1.003	1.000	1.000	1.000	1.001	1.000	0.996	1.000	0.998	1.000	*1.225*	*1.265*	*1.144*	*1.265*
	556.78	17821	1.003	1.000	0.998	1.000	1.000	1.000	0.999	1.000	0.999	1.000	0.995	1.000	**0.594**	**0.343**	**0.562**	**0.343**
l152lav	5.51	23	0.994	1.000	0.989	1.000	0.994	1.000	0.994	1.000	0.995	1.000	1.005	1.000	*2.278*	*1.520*	1.035	*1.244*
	1.67	31	0.985	1.000	0.993	1.000	0.985	1.000	0.993	1.000	0.989	1.000	0.966	1.000	*2.131*	*1.122*	*1.225*	*1.183*
	2.93	50	1.000	1.000	0.995	1.000	0.992	1.000	1.000	1.000	1.003	1.000	1.008	1.000	*3.046*	*1.367*	0.962	0.967
	2.34	20	0.985	1.000	0.994	1.000	0.991	1.000	0.991	1.000	0.985	1.000	1.003	1.000	*3.713*	*2.008*	*1.275*	*1.342*
	3.02	52	0.995	1.000	1.000	1.000	0.995	1.000	0.993	1.000	0.998	1.000	1.002	1.000	*2.167*	*1.204*	**0.891**	**0.921**
lectsched-4-obj	27.04	805	**0.753**	**0.215**	*1.223*	**0.740**	1.004	1.000	1.009	**0.924**	1.005	1.000	**0.730**	**0.314**	**0.748**	**0.215**	0.978	*1.608*
	23.16	868	*1.201*	**0.288**	**0.813**	**0.525**	1.029	*1.080*	**0.887**	**0.765**	0.988	1.000	**0.666**	**0.311**	*1.201*	**0.288**	0.995	*1.282*
	86.08	1061	**0.288**	**0.264**	**0.416**	**0.216**	**0.627**	**0.461**	1.020	1.006	**0.385**	**0.696**	**0.458**	**0.146**	**0.265**	**0.121**	**0.384**	**0.696**
	26.83	619	**0.327**	**0.082**	**0.768**	**0.367**	**0.928**	**0.540**	**0.926**	**0.772**	**0.257**	**0.082**	*2.333*	**0.477**	**0.330**	**0.082**	**0.257**	**0.082**
	22.73	745	**0.909**	**0.253**	1.038	**0.805**	1.005	1.000	0.992	0.954	1.004	1.000	*1.484*	**0.910**	**0.913**	**0.253**	**0.701**	**0.647**
lseu	0.75	268	1.011	1.000	1.011	1.000	1.006	1.000	1.000	1.000	1.011	1.000	1.034	1.000	*1.566*	*1.095*	1.006	0.986
	0.50	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.010	1.000	1.000
	0.51	205	0.993	1.000	1.000	1.000	0.993	1.000	0.993	1.000	0.993	1.000	1.000	1.000	*1.238*	**0.866**	0.993	**0.931**
	0.50	91	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**0.738**	1.000	0.969
	0.50	191	1.007	1.000	1.000	1.000	1.000	1.000	1.007	1.000	1.007	1.000	1.007	1.000	*1.380*	**0.670**	1.000	**0.680**
m100n500k4r1	3600.00	2166065	1.000	*1.118*	1.000	**0.786**	1.000	0.998	1.000	1.001	1.000	1.001	1.000	**0.777**	1.000	**0.780**	1.000	*1.171*
	3600.00	2266017	1.000	1.035	1.000	**0.712**	1.000	0.995	1.000	0.999	1.000	0.998	1.000	**0.701**	1.000	**0.782**	1.000	*1.059*
	3600.00	2611447	1.000	**0.884**	1.000	**0.646**	1.000	0.998	1.000	1.002	1.000	1.001	1.000	**0.640**	1.000	**0.559**	1.000	**0.930**
	3600.00	2305045	1.000	**0.937**	1.000	**0.723**	1.000	0.998	1.000	0.999	1.000	0.999	1.000	**0.723**	1.000	**0.640**	1.000	0.989
	3600.00	2226238	1.000	**0.833**	1.000	**0.733**	1.000	0.991	1.000	0.999	1.000	0.997	1.000	**0.732**	1.000	**0.645**	1.000	**0.923**
macrophage	125.50	5163	1.001	1.000	1.006	1.000	1.001	1.000	1.005	1.000	1.001	1.000	1.001	1.000	*1.774*	*1.158*	**0.911**	**0.701**
	157.18	7241	0.999	1.000	0.999	1.000	0.998	1.000	1.000	1.000	0.999	1.000	0.998	1.000	*1.535*	*1.184*	**0.948**	**0.852**
	209.11	9131	1.000	1.000	0.999	1.000	1.002	1.000	0.998	1.000	0.999	1.000	0.999	1.000	*1.438*	*1.250*	**0.821**	*1.053*
	162.53	7927	1.000	1.000	1.002	1.000	1.002	1.000	1.000	1.000	0.998	1.000	1.000	1.000	*1.876*	*1.088*	*1.083*	**0.840**
	121.37	5239	0.999	1.000	0.997	1.000	0.998	1.000	1.000	1.000	1.001	1.000	0.997	1.000	*1.987*	*1.355*	*1.059*	*1.071*

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Table C.1: Computational results on MMM-IP: Impact of criteria.

	default		degeneracy		dualbound		leaves		obj		nsols		sblps		nochecks		onlyroot	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
manna81	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.007	1.000	1.020	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.013	1.000	1.013	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.013	1.000	1.033	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.013	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.007	1.000	1.033	1.000
markshare1	3600.00	19010451	1.000	**0.931**	1.000	**0.786**	1.000	0.996	1.000	1.000	1.000	0.996	1.000	**0.797**	1.000	**0.924**	1.000	*1.083*
	3600.00	20192578	1.000	**0.862**	1.000	**0.893**	1.000	0.999	1.000	0.997	1.000	1.000	1.000	**0.890**	1.000	**0.856**	1.000	1.017
	3600.00	19529435	1.000	**0.919**	1.000	**0.907**	1.000	1.000	1.000	0.998	1.000	0.997	1.000	**0.919**	1.000	**0.918**	1.000	*1.219*
	3600.00	20381558	1.000	**0.898**	1.000	**0.865**	1.000	0.998	1.000	1.001	1.000	1.002	1.000	**0.818**	1.000	**0.903**	1.000	1.017
	3600.00	21608999	1.000	**0.797**	1.000	**0.808**	1.000	1.004	1.000	1.000	1.000	0.996	1.000	**0.806**	1.000	**0.795**	1.000	*1.090*
markshare2	3600.00	4050504	1.000	**0.843**	1.000	*1.137*	1.000	0.995	1.000	0.991	1.000	0.995	1.000	*1.143*	1.000	**0.846**	1.000	0.958
	3600.00	5646401	1.000	**0.697**	1.000	**0.783**	1.000	1.001	1.000	1.000	1.000	1.000	1.000	**0.787**	1.000	**0.697**	1.000	**0.636**
	3600.00	3589038	1.000	1.026	1.000	1.002	1.000	1.002	1.000	0.996	1.000	0.998	1.000	1.002	1.000	1.026	1.000	*1.083*
	3600.00	4244067	1.000	*1.069*	1.000	*1.098*	1.000	1.001	1.000	1.003	1.000	1.001	1.000	*1.106*	1.000	*1.069*	1.000	**0.891**
	3600.00	5150867	1.000	**0.830**	1.000	**0.737**	1.000	1.002	1.000	0.996	1.000	0.999	1.000	**0.736**	1.000	**0.832**	1.000	**0.948**
mcsched	285.92	13689	0.999	1.000	0.997	1.000	0.998	1.000	1.012	1.000	0.998	1.000	1.000	1.000	*1.093*	**0.678**	**0.820**	**0.732**
	271.88	11373	0.999	1.000	0.998	1.000	1.002	1.000	0.999	1.000	1.001	1.000	1.000	1.000	*3.196*	*1.747*	*1.459*	*1.710*
	233.97	10059	0.996	1.000	0.997	1.000	1.005	1.000	0.998	1.000	0.997	1.000	1.001	1.000	*2.468*	*1.296*	*1.287*	*1.310*
	286.25	12496	0.997	1.000	0.998	1.000	0.995	1.000	0.998	1.000	0.998	1.000	0.997	1.000	*2.450*	*1.245*	*1.055*	*1.146*
	270.69	10373	1.005	1.000	1.000	1.000	1.005	1.000	1.000	1.000	1.001	1.000	1.001	1.000	*1.542*	0.996	1.007	0.992
mine-166-5	58.69	1569	0.995	1.000	0.995	1.000	0.997	1.000	0.993	1.000	1.020	1.000	1.001	1.000	**0.776**	1.022	**0.851**	*2.359*
	57.78	1191	0.990	1.000	0.992	1.000	0.996	1.000	0.990	1.000	0.990	1.000	0.991	1.000	**0.920**	**0.930**	*1.110*	**0.901**
	46.45	2244	1.001	1.000	1.004	1.000	1.006	1.000	1.007	1.000	1.001	1.000	1.003	1.000	*1.103*	*1.067*	*1.132*	**0.650**
	64.93	139	1.006	1.000	1.004	1.000	1.005	1.000	1.001	1.000	1.005	1.000	1.002	1.000	**0.711**	*5.397*	**0.619**	*6.515*
	42.28	2863	1.000	1.000	1.000	1.000	1.001	1.000	1.000	1.000	1.001	1.000	0.998	1.000	*1.165*	**0.555**	0.994	**0.873**
mine-90-10	276.07	51926	1.002	1.000	1.001	1.000	*1.157*	*1.090*	0.999	1.000	1.000	1.000	1.003	1.000	1.033	**0.750**	**0.767**	**0.596**
	125.32	22195	0.998	1.000	1.005	1.000	0.998	1.000	0.999	1.000	1.003	1.000	1.001	1.000	*4.652*	*3.660*	*1.749*	*1.438*
	173.25	25979	1.001	1.000	1.004	1.000	0.999	1.000	0.999	1.000	1.004	1.000	0.999	1.000	*1.687*	*1.060*	*2.725*	*2.264*
	500.83	92879	1.003	1.000	1.000	1.000	*1.324*	*1.061*	0.999	1.000	0.999	1.000	0.999	1.000	**0.809**	**0.459**	**0.556**	**0.457**
	236.18	40409	1.005	1.000	1.003	1.000	**0.907**	*1.242*	1.004	1.000	1.002	1.000	1.013	1.000	*2.162*	*1.767*	**0.762**	**0.592**
misc03	1.39	398	1.004	1.000	1.004	1.000	1.000	1.000	1.013	1.000	1.004	1.000	0.983	1.000	**0.799**	**0.267**	**0.711**	**0.263**
	0.71	15	1.000	1.000	0.994	1.000	1.012	1.000	1.006	1.000	*1.076*	*1.226*	1.006	1.000	*1.427*	*1.226*	*1.094*	*1.226*
	0.70	19	1.018	1.000	0.994	1.000	1.006	1.000	1.018	1.000	*1.165*	*1.487*	0.976	1.000	*1.512*	*1.471*	*1.176*	*1.487*
	1.00	111	0.990	1.000	1.010	1.000	1.010	1.000	1.000	1.000	0.985	1.000	1.000	1.000	1.015	**0.763**	**0.855**	**0.706**
	0.66	15	0.988	1.000	1.000	1.000	0.988	1.000	0.988	1.000	*1.187*	*1.609*	0.988	1.000	*1.608*	*1.435*	*1.151*	*1.609*
misc07	38.05	28289	1.006	1.000	1.027	1.000	0.998	1.000	0.998	1.000	*1.089*	*1.188*	1.000	1.000	*1.496*	**0.758**	*1.087*	*1.188*
	36.66	29782	0.995	1.000	0.996	1.000	0.998	1.000	0.999	1.000	1.001	1.000	1.004	1.000	*2.177*	1.017	**0.946**	*1.080*

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Table C.1: Computational results on MMM-IP: Impact of criteria.

	default		degeneracy		dualbound		leaves		obj		nsols		sblps		nochecks		onlyroot	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	21.56	17632	0.995	1.000	0.993	1.000	0.998	1.000	1.004	1.000	1.001	1.000	0.993	1.000	*3.660*	*1.598*	*2.274*	*2.333*
	45.95	38975	0.997	1.000	0.994	1.000	0.996	1.000	1.004	1.000	1.005	1.000	1.005	1.000	*1.340*	**0.588**	**0.812**	**0.806**
	30.94	29476	0.988	1.000	1.001	1.000	0.998	1.000	0.990	1.000	*1.082*	**0.937**	0.994	1.000	*1.266*	**0.557**	*1.084*	**0.937**
mitre	10.20	1	*1.390*	1.000	0.996	1.000	1.012	1.000	*1.054*	1.000	0.991	1.000	*1.071*	1.000	*1.381*	1.000	*1.374*	1.000
	10.28	1	*1.469*	1.000	0.989	1.000	1.006	1.000	0.991	1.000	*1.481*	1.000	0.989	1.000	*1.449*	1.000	*1.456*	1.000
	10.94	1	*1.384*	1.000	0.955	1.000	0.961	1.000	**0.946**	1.000	*1.357*	1.000	0.955	1.000	*1.389*	1.000	*1.447*	1.000
	10.45	1	*1.412*	1.000	0.994	1.000	0.990	1.000	0.987	1.000	0.991	1.000	0.979	1.000	*1.397*	1.000	*1.400*	1.000
	13.12	1	1.019	1.000	0.996	1.000	0.984	1.000	0.982	1.000	1.008	1.000	0.994	1.000	1.046	1.000	*1.055*	1.000
mod008	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.54	2	0.994	1.000	1.006	1.000	1.000	1.000	0.994	1.000	0.994	1.000	1.000	1.000	1.026	1.000	1.032	1.000
	0.52	2	1.013	1.000	1.013	1.000	1.007	1.000	0.993	1.000	0.987	1.000	1.007	1.000	1.026	0.990	1.020	0.990
	0.52	1	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.020	1.000	1.033	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
mod010	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	*1.460*	1.000	*1.273*	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	*1.193*	1.000	*1.180*	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	*1.233*	1.010	*1.273*	1.010
	0.52	2	1.007	1.000	1.020	1.000	0.993	1.000	0.993	1.000	1.007	1.000	1.007	1.000	*1.329*	1.000	*1.197*	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	*1.347*	1.010	*1.320*	1.010
mzzv11	332.43	2022	0.999	1.000	1.000	1.000	0.995	1.000	1.005	1.000	0.995	1.000	0.996	1.000	*1.490*	**0.583**	**0.932**	**0.330**
	229.41	959	1.002	1.000	0.999	1.000	1.001	1.000	1.005	1.000	1.002	1.000	1.003	1.000	*1.453*	**0.818**	*1.573*	*1.220*
	310.05	1421	1.004	1.000	1.000	1.000	1.001	1.000	0.995	1.000	0.999	1.000	0.999	1.000	**0.910**	**0.415**	*1.175*	**0.525**
	327.03	1579	0.987	1.000	1.001	1.000	0.995	1.000	0.995	1.000	0.994	1.000	0.993	1.000	1.000	**0.378**	0.964	**0.392**
	186.14	627	1.000	1.000	1.003	1.000	1.003	1.000	1.008	1.000	1.007	1.000	1.007	1.000	*1.746*	**0.791**	*1.458*	**0.770**
mzzv42z	152.40	265	0.992	1.000	0.996	1.000	0.999	1.000	0.993	1.000	0.991	1.000	0.999	1.000	*2.086*	*1.477*	0.984	**0.753**
	131.25	125	0.999	1.000	0.993	1.000	0.993	1.000	0.983	1.000	0.992	1.000	*1.107*	*1.053*	*2.096*	*1.636*	*1.692*	*1.667*
	197.62	200	1.006	1.000	1.003	1.000	1.006	1.000	1.005	1.000	1.002	1.000	1.016	**0.923**	*2.262*	*1.597*	*1.436*	*1.117*
	213.83	456	1.002	1.000	1.001	1.000	1.001	1.000	1.006	1.000	0.996	1.000	**0.945**	**0.736**	*1.504*	**0.845**	*1.677*	0.968
	167.65	300	0.999	1.000	0.998	1.000	0.998	1.000	1.000	1.000	1.007	1.000	1.003	1.000	*1.347*	**0.657**	*1.143*	**0.695**
neos-1109824	37.52	1796	0.996	1.000	1.037	1.000	0.995	1.000	0.988	1.000	*1.572*	*2.657*	1.018	1.000	*2.154*	*2.246*	*1.553*	*2.657*
	46.67	3438	0.998	1.000	1.027	*1.072*	0.996	1.000	0.998	1.000	0.971	0.962	**0.782**	**0.594**	*1.320*	**0.810**	0.969	0.962
	35.16	1913	0.995	1.000	1.002	1.000	0.997	1.000	1.002	1.000	0.995	1.000	*1.079*	0.966	*1.478*	0.997	*1.373*	*1.906*
	77.65	8290	0.996	1.000	1.001	1.000	0.997	1.000	1.000	1.000	**0.693**	**0.534**	1.000	1.000	0.984	**0.445**	**0.695**	**0.534**
	39.64	2247	0.990	1.000	0.992	1.000	0.991	1.000	0.994	1.000	*1.121*	*1.077*	1.030	**0.933**	*1.926*	*1.546*	*1.120*	*1.077*
neos-1337307	3600.00	299554	1.000	1.013	1.000	1.008	1.000	0.990	1.000	1.001	1.000	*1.175*	1.000	0.993	1.000	**0.167**	1.000	*1.142*
	3600.00	268930	1.000	0.999	1.000	1.001	1.000	0.998	1.000	0.999	1.000	*1.085*	1.000	0.999	1.000	**0.169**	1.000	**0.837**
	3600.00	350002	1.000	1.003	1.000	0.996	1.000	1.004	1.000	1.005	1.000	1.013	1.000	0.999	1.000	**0.153**	1.000	*1.101*
	3600.00	300182	1.000	1.003	1.000	0.998	1.000	0.999	1.000	1.003	1.000	*1.136*	1.000	0.998	1.000	**0.152**	1.000	*1.124*

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	default		degeneracy		dualbound		leaves		obj		nsols		sblps		nochecks		onlyroot	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	3600.00	367948	1.000	1.015	1.000	1.008	1.000	1.001	1.000	1.005	1.000	**0.749**	1.000	1.004	1.000	**0.112**	1.000	0.986
neos-1601936	2034.60	1453	0.999	1.000	*1.714*	*3.615*	0.998	1.000	0.999	1.000	*1.769*	**0.679**	1.002	1.000	*1.769*	*1.201*	*1.769*	**0.679**
	3600.00	2861	1.000	1.004	1.000	1.039	1.000	1.004	1.000	0.997	1.000	**0.393**	1.000	1.002	1.000	**0.356**	1.000	**0.609**
	1348.55	2661	0.993	1.000	*2.668*	*5.411*	1.001	1.000	1.001	1.000	*2.668*	**0.548**	1.000	1.000	*2.668*	**0.541**	*2.668*	**0.528**
	3600.00	6917	1.000	1.000	1.000	*1.168*	1.000	1.000	1.000	1.004	1.000	**0.429**	1.000	1.000	1.000	**0.831**	**0.898**	**0.158**
	3600.00	6139	1.000	1.000	1.000	**0.686**	1.000	1.000	1.000	1.000	**0.419**	**0.176**	1.000	1.000	1.000	**0.441**	**0.417**	**0.176**
neos-686190	83.42	4906	0.998	1.000	0.998	1.000	0.992	1.000	0.998	1.000	1.001	1.000	1.000	1.000	*7.579*	*3.397*	*1.703*	*2.367*
	86.19	6047	1.004	1.000	1.001	1.000	1.000	1.000	0.999	1.000	1.001	1.000	0.999	1.000	*8.670*	*3.407*	*4.366*	*6.493*
	114.74	9156	1.005	1.000	1.000	1.000	0.999	1.000	0.998	1.000	0.999	1.000	1.001	1.000	*3.742*	**0.651**	**0.736**	**0.632**
	116.53	9998	1.006	1.000	1.005	1.000	1.006	1.000	1.000	1.000	0.999	1.000	1.004	1.000	*3.255*	**0.460**	**0.681**	**0.564**
	121.04	9806	0.998	1.000	1.002	1.000	0.999	1.000	0.998	1.000	1.004	1.000	0.997	1.000	*2.484*	**0.493**	**0.627**	**0.572**
neos-849702	114.99	1680	*1.802*	**0.595**	**0.862**	**0.835**	**0.866**	**0.835**	*1.801*	**0.595**	*1.802*	**0.595**	*1.731*	*4.759*	*1.802*	**0.595**	*9.601*	*11.858*
	353.12	77703	*2.900*	**0.364**	*2.216*	*4.411*	*2.214*	*4.411*	*2.910*	**0.364**	*2.907*	**0.364**	*9.463*	*19.062*	*2.919*	**0.364**	*2.830*	*2.084*
	357.57	9988	*2.795*	**0.359**	**0.511**	**0.342**	**0.514**	**0.342**	*2.802*	**0.359**	*2.797*	**0.359**	*2.369*	*2.377*	*2.799*	**0.359**	*2.111*	**0.080**
	261.49	16745	1.021	**0.048**	*1.101*	1.032	*1.100*	1.032	1.019	**0.048**	1.016	**0.048**	*1.557*	*1.159*	1.023	**0.048**	*5.019*	*1.101*
	143.57	25014	*1.981*	**0.335**	*2.290*	*4.955*	*2.283*	*4.955*	*1.981*	**0.335**	*1.985*	**0.335**	*6.512*	*16.346*	*1.980*	**0.335**	*5.285*	*5.390*
neos-934278	3600.00	1175	1.000	0.993	1.000	0.991	1.000	0.993	1.000	0.993	1.000	0.993	1.000	1.000	1.000	**0.335**	1.000	**0.340**
	3600.00	267	1.000	1.005	1.000	1.005	1.000	1.005	1.000	1.005	1.000	1.014	1.000	1.005	1.000	*1.101*	1.000	*1.153*
	3600.00	266	1.000	1.000	1.000	1.003	1.000	1.008	1.000	0.989	1.000	1.000	1.000	1.008	1.000	*1.124*	1.000	*1.182*
	3600.00	399	1.000	1.020	1.000	0.953	1.000	1.016	1.000	1.014	1.000	1.014	1.000	1.012	1.000	**0.835**	1.000	**0.857**
	3600.00	523	1.000	1.002	1.000	0.998	1.000	1.003	1.000	1.000	1.000	1.003	1.000	1.000	1.000	**0.680**	1.000	**0.717**
neos18	24.17	1378	**0.363**	**0.121**	0.993	1.000	0.993	1.000	0.981	1.047	0.997	1.000	**0.575**	**0.287**	**0.354**	**0.121**	**0.915**	**0.918**
	21.26	1604	*1.162*	**0.653**	*1.403*	*1.457*	1.028	*1.199*	0.996	1.000	1.000	1.000	*1.429*	*1.072*	0.967	**0.467**	1.031	*1.431*
	23.36	1646	*1.229*	**0.684**	0.993	1.000	0.994	1.000	0.998	1.000	0.995	1.000	**0.840**	**0.248**	*1.218*	**0.684**	**0.914**	**0.824**
	19.21	996	**0.812**	**0.443**	**0.840**	**0.849**	0.997	1.000	0.997	1.000	1.021	1.000	**0.789**	**0.366**	**0.810**	**0.443**	*1.059*	*1.091*
	22.07	1049	0.987	**0.925**	**0.855**	**0.634**	1.004	1.000	1.001	1.000	0.997	1.000	**0.906**	**0.657**	**0.948**	**0.795**	*1.174*	*2.047*
ns1208400	2439.01	780	**0.385**	**0.219**	**0.396**	**0.178**	**0.146**	**0.062**	0.994	1.000	**0.485**	**0.271**	**0.296**	**0.090**	**0.485**	**0.271**	**0.482**	**0.404**
	1985.63	5751	*1.378*	*1.450*	**0.948**	**0.886**	*1.673*	**0.733**	1.003	1.000	*1.395*	*1.451*	**0.415**	**0.213**	*1.390*	*1.450*	**0.486**	**0.380**
	1467.85	1351	**0.363**	**0.355**	**0.810**	**0.504**	**0.415**	**0.283**	1.000	1.000	**0.368**	**0.355**	**0.713**	**0.156**	**0.367**	**0.355**	**0.673**	**0.768**
	3600.00	2617	**0.071**	**0.122**	**0.493**	*1.157*	**0.274**	**0.476**	**0.309**	**0.607**	**0.070**	**0.122**	**0.244**	**0.332**	**0.071**	**0.122**	**0.147**	**0.400**
	2388.79	3984	**0.551**	**0.313**	**0.915**	*1.198*	**0.649**	**0.464**	0.999	1.000	**0.054**	**0.069**	**0.434**	**0.229**	**0.051**	**0.068**	**0.533**	**0.656**
ns1688347	55.09	818	**0.939**	0.975	0.998	1.013	*1.209*	*1.666*	*1.084*	*1.283*	1.040	**0.935**	1.000	1.000	0.999	*1.103*	1.038	**0.935**
	45.64	422	**0.931**	**0.518**	0.996	1.000	*1.062*	**0.892**	0.986	0.969	*1.391*	*1.591*	0.998	1.000	*1.058*	**0.839**	*1.396*	*1.591*
	106.90	1690	*1.509*	*1.626*	1.000	1.000	0.999	**0.911**	*1.152*	**0.855**	*1.478*	*1.240*	1.001	1.000	**0.884**	**0.571**	*1.492*	*1.240*
	139.57	1219	0.957	1.024	1.018	*1.095*	0.994	1.000	**0.945**	*1.088*	*1.130*	0.999	0.998	1.000	**0.682**	**0.329**	**0.771**	**0.500**
	55.82	414	**0.924**	**0.591**	0.999	1.000	**0.719**	**0.608**	0.996	1.000	*1.169*	*1.244*	1.002	1.000	**0.850**	**0.550**	*1.169*	*1.244*

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Table C.1: Computational results on `MMM-IP`: Impact of criteria.

Instance	default		degeneracy		dualbound		leaves		obj		nsols		sblps		nochecks		onlyroot	
	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
ns1830653	132.81	5720	1.002	1.000	1.000	1.000	**0.810**	**0.829**	1.001	1.000	*1.130*	1.028	0.998	1.000	*1.142*	**0.663**	*1.132*	1.028
	123.49	5512	1.003	1.000	1.002	1.000	*1.248*	*1.054*	1.001	1.000	*1.221*	*1.285*	1.003	1.000	*1.548*	*1.133*	*1.223*	*1.285*
	161.13	10467	0.999	1.000	1.002	1.000	0.953	*1.090*	1.000	1.000	*1.078*	0.985	**0.803**	**0.886**	*1.229*	**0.479**	*1.093*	0.985
	143.05	7519	1.001	1.000	**0.826**	**0.713**	*1.065*	1.011	0.999	1.000	*1.108*	*1.177*	**0.785**	**0.589**	*1.193*	**0.833**	*1.104*	*1.177*
	146.20	5836	0.999	1.000	0.999	1.000	**0.779**	**0.639**	0.999	1.000	*1.158*	**0.738**	**0.851**	**0.746**	1.028	**0.406**	*1.162*	**0.738**
nsrand-ipx	422.05	50124	0.995	1.000	1.011	1.000	0.999	1.000	0.996	1.000	1.002	1.000	*1.302*	**0.946**	*6.327*	**0.938**	*1.897*	*1.892*
	643.65	86869	0.992	1.000	1.002	1.000	0.996	1.000	0.998	1.000	0.996	1.000	*1.275*	**0.923**	*4.263*	**0.891**	**0.503**	**0.378**
	568.28	56575	1.002	1.000	1.011	1.000	1.001	1.000	1.000	1.000	1.002	1.000	*1.063*	0.996	*6.326*	**0.715**	*1.101*	1.016
	582.50	61056	1.000	1.000	0.998	1.000	1.001	1.000	1.003	1.000	1.008	1.000	*2.283*	**0.885**	*5.237*	*1.122*	**0.898**	**0.893**
	367.03	38012	0.991	1.000	0.995	1.000	0.993	1.000	0.999	1.000	0.995	1.000	*1.142*	1.032	*9.405*	*1.958*	*1.867*	*2.088*
opt1217	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
p0033	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
p0201	0.55	5	0.994	1.000	1.006	1.000	0.987	1.000	1.000	1.000	0.981	1.000	1.000	1.000	0.968	*1.057*	0.968	*1.057*
	0.71	9	1.018	1.000	1.006	1.000	1.012	1.000	1.012	1.000	1.000	1.000	1.023	1.000	**0.924**	0.982	**0.924**	0.982
	1.59	5	1.019	1.000	1.008	1.000	1.000	1.000	1.000	1.000	1.015	1.000	1.023	1.000	**0.749**	*1.210*	**0.819**	*2.419*
	0.90	13	1.000	1.000	0.995	1.000	1.011	1.000	1.005	1.000	1.005	1.000	0.989	1.000	*1.058*	*1.088*	**0.911**	*1.088*
	0.91	59	0.990	1.000	0.990	1.000	1.000	1.000	0.990	1.000	0.995	1.000	0.995	1.000	**0.890**	**0.761**	**0.812**	**0.761**
p0282	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	3	1.000	1.000	1.000	1.000	1.000	1.000	1.007	1.000	1.000	1.000	1.013	1.000	1.000	0.990	1.033	1.000
	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
p0548	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
p2756	2.46	5	1.014	1.000	1.014	1.000	1.000	1.000	1.006	1.000	1.012	1.000	1.014	1.000	**0.942**	*1.067*	**0.861**	0.990
	3.33	5	1.000	1.000	1.005	1.000	1.005	1.000	1.005	1.000	1.002	1.000	1.012	1.000	*1.102*	1.010	0.998	0.990

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Table C.1: Computational results on MMM-IP: Impact of criteria.

	default		degeneracy		dualbound		leaves		obj		nsols		sblps		nochecks		onlyroot	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	2.16	3	0.991	1.000	0.987	1.000	0.994	1.000	0.981	1.000	0.991	1.000	0.978	1.000	*1.073*	1.010	0.981	1.000
	2.60	3	0.983	1.000	0.994	1.000	0.994	1.000	0.983	1.000	0.983	1.000	0.978	1.000	0.969	1.010	0.964	1.019
	1.22	2	1.027	1.000	1.041	1.000	1.023	1.000	1.027	1.000	1.023	1.000	1.014	1.000	*1.077*	1.010	*1.063*	1.010
protfold	3600.00	4825	1.000	**0.685**	1.000	1.007	1.000	1.009	1.000	0.990	1.000	1.008	1.000	1.002	1.000	**0.575**	1.000	**0.530**
	3600.00	8262	1.000	**0.315**	1.000	1.001	1.000	1.011	1.000	0.994	1.000	0.997	1.000	1.001	1.000	**0.303**	1.000	**0.289**
	3600.00	5818	1.000	**0.481**	1.000	0.999	1.000	0.997	1.000	0.999	1.000	0.995	1.000	0.998	1.000	**0.558**	1.000	**0.358**
	3600.00	7269	1.000	**0.262**	1.000	1.002	1.000	1.001	1.000	1.001	1.000	1.006	1.000	1.001	1.000	**0.264**	1.000	**0.231**
	3600.00	4748	1.000	**0.344**	1.000	0.998	1.000	**0.848**	1.000	1.000	1.000	1.000	1.000	1.003	1.000	**0.415**	1.000	**0.299**
pw-myciel4	3600.00	519342	1.000	**0.695**	1.000	**0.895**	1.000	0.999	**0.662**	**0.587**	1.000	1.000	1.000	**0.858**	1.000	*1.087*	1.000	**0.868**
	3600.00	442617	1.000	**0.826**	**0.800**	**0.789**	1.000	0.999	**0.932**	0.954	1.000	1.000	1.000	**0.858**	1.000	**0.636**	1.000	1.040
	3600.00	389396	1.000	**0.826**	1.000	*1.146*	1.000	0.994	1.000	0.974	1.000	0.992	1.000	*1.053*	1.000	**0.780**	1.000	**0.910**
	2920.77	395762	*1.232*	**0.905**	*1.232*	**0.938**	1.006	1.000	*1.232*	**0.872**	1.000	1.000	*1.232*	**0.943**	*1.232*	*1.125*	*1.232*	0.984
	3600.00	405310	**0.848**	**0.934**	1.000	0.991	1.000	1.000	**0.939**	1.044	1.000	1.001	1.000	1.031	0.971	**0.834**	1.000	*1.204*
qnet1	4.52	33	1.004	1.000	1.005	1.000	1.013	1.000	0.998	1.000	1.005	1.000	1.007	1.000	**0.455**	**0.797**	**0.455**	**0.797**
	3.09	3	1.007	1.000	1.005	1.000	1.005	1.000	1.010	1.000	1.010	1.000	0.998	1.000	*1.086*	0.990	**0.804**	1.000
	3.94	29	0.996	1.000	1.002	1.000	0.994	1.000	1.004	1.000	1.000	1.000	1.002	1.000	*1.138*	1.000	**0.949**	1.000
	2.23	3	1.009	1.000	1.000	1.000	1.006	1.000	1.003	1.000	1.009	1.000	1.000	1.000	*1.161*	*1.087*	*1.071*	1.010
	3.69	34	1.004	1.000	0.989	1.000	0.998	1.000	0.994	1.000	0.989	1.000	1.000	1.000	*1.198*	0.970	**0.887**	1.022
qnet1_o	3.93	27	0.988	1.000	0.992	1.000	0.996	1.000	1.002	1.000	0.996	1.000	0.988	1.000	**0.919**	**0.929**	**0.836**	**0.929**
	3.35	24	1.007	1.000	1.005	1.000	1.000	1.000	1.002	1.000	0.998	1.000	1.009	1.000	*1.094*	0.992	**0.897**	0.992
	3.37	15	1.005	1.000	1.009	1.000	0.995	1.000	1.011	1.000	1.014	1.000	1.002	1.000	**0.712**	**0.904**	**0.616**	**0.887**
	1.66	2	1.004	1.000	0.996	1.000	1.000	1.000	0.992	1.000	1.004	1.000	1.008	1.000	*1.143*	1.000	0.996	1.000
	1.83	3	1.004	1.000	1.007	1.000	1.007	1.000	1.000	1.000	1.007	1.000	1.004	1.000	*1.085*	1.000	1.018	1.000
reblock67	222.59	49530	1.002	1.000	0.999	1.000	1.007	1.000	0.999	1.000	0.997	1.000	0.995	1.000	*2.701*	*1.225*	**0.803**	**0.598**
	161.89	40625	1.000	1.000	0.997	1.000	1.000	1.000	0.996	1.000	0.998	1.000	1.000	1.000	*2.270*	**0.943**	*1.272*	*1.214*
	194.41	42542	1.001	1.000	1.002	1.000	**0.857**	**0.853**	0.997	1.000	1.003	1.000	1.001	1.000	*2.191*	0.951	**0.902**	**0.876**
	199.06	52613	1.006	1.000	1.003	1.000	0.992	1.032	1.006	1.000	1.005	1.000	1.001	1.000	*3.355*	*1.638*	**0.868**	**0.767**
	239.84	57566	0.997	1.000	0.997	1.000	0.994	1.000	0.997	1.000	0.996	1.000	0.997	1.000	*1.707*	*1.170*	**0.716**	**0.795**
rmine6	971.86	111047	1.000	1.000	1.006	1.000	1.002	1.000	1.000	1.000	1.001	1.000	0.999	1.000	*1.724*	*1.068*	*1.441*	**0.906**
	883.48	89213	0.999	1.000	1.000	1.000	0.990	1.000	0.999	1.000	1.002	1.000	1.002	1.000	*2.249*	*1.574*	**0.945**	**0.921**
	775.32	91530	1.002	1.000	1.002	1.000	1.000	1.000	1.001	1.000	1.002	1.000	1.000	1.000	*2.090*	*1.268*	1.037	1.014
	740.58	85429	1.002	1.000	1.000	1.000	0.999	1.000	1.005	1.000	0.999	1.000	0.992	1.000	*1.817*	*1.249*	*1.310*	*1.072*
	771.48	76017	1.002	1.000	1.001	1.000	1.002	1.000	1.001	1.000	0.998	1.000	1.001	1.000	*1.581*	*1.168*	*1.134*	*1.144*
rococoC10-001000	601.83	46983	1.003	1.000	1.000	1.000	0.998	1.000	0.998	1.000	0.998	1.000	1.000	1.000	*2.365*	*1.898*	*2.192*	*1.817*
	833.40	75156	1.003	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.002	1.000	*2.401*	*1.509*	*1.679*	*1.377*
	517.62	37178	0.998	1.000	1.002	1.000	1.003	1.000	*1.092*	*1.105*	1.002	1.000	1.001	1.000	*1.872*	*1.710*	*1.428*	*1.458*
	892.04	51410	1.001	1.000	1.002	1.000	0.999	1.000	1.001	1.000	1.003	1.000	1.003	1.000	*1.737*	*1.994*	*1.076*	*1.344*

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Table C.1: Computational results on MMM-IP: Impact of criteria.

	default		degeneracy		dualbound		leaves		obj		nsols		sblps		nochecks		onlyroot	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	1047.39	66016	1.001	1.000	1.000	1.000	1.001	1.000	1.001	1.000	1.003	1.000	1.003	1.000	*2.255*	*1.863*	*1.367*	*1.434*
seymour	3600.00	102303	1.000	0.996	1.000	0.993	1.000	0.997	1.000	0.999	1.000	0.997	1.000	1.001	1.000	**0.717**	1.000	**0.768**
	3600.00	120875	1.000	0.999	1.000	1.001	1.000	1.005	1.000	0.997	1.000	1.005	1.000	1.001	1.000	**0.626**	1.000	**0.656**
	3600.00	123371	1.000	1.006	1.000	1.006	1.000	1.008	1.000	1.010	1.000	1.010	1.000	1.006	1.000	**0.737**	1.000	**0.791**
	3600.00	107935	1.000	1.005	1.000	1.003	1.000	1.004	1.000	1.003	1.000	1.002	1.000	1.011	1.000	**0.836**	1.000	**0.943**
	3600.00	97288	1.000	1.003	1.000	1.001	1.000	1.006	1.000	1.001	1.000	1.003	1.000	1.002	1.000	1.002	1.000	*1.069*
sp98ir	57.90	3948	1.003	1.000	1.009	1.000	1.003	1.000	1.020	1.000	1.010	1.000	1.008	1.000	*2.980*	*1.355*	*1.637*	*1.467*
	65.87	4178	1.001	1.000	1.003	1.000	1.003	1.000	1.003	1.000	1.004	1.000	1.007	1.000	*2.428*	*1.260*	*1.115*	*1.144*
	67.64	4735	1.004	1.000	1.002	1.000	1.001	1.000	1.003	1.000	1.001	1.000	1.008	1.000	*3.056*	*1.357*	*1.306*	*1.249*
	72.68	4603	0.997	1.000	1.002	1.000	1.003	1.000	0.999	1.000	1.001	1.000	1.005	1.000	*2.275*	**0.892**	**0.890**	**0.882**
	70.05	4780	0.997	1.000	0.997	1.000	0.995	1.000	0.999	1.000	1.005	1.000	1.004	1.000	*2.109*	*1.134*	*1.088*	*1.248*
stein27	1.12	2749	1.024	1.000	0.995	1.000	1.028	1.000	1.024	1.000	1.033	1.000	0.991	1.000	*1.491*	*1.081*	*1.094*	*1.081*
	1.19	2699	1.018	1.000	1.009	1.000	1.005	1.000	1.009	1.000	1.027	1.000	1.023	1.000	*1.502*	1.025	1.014	1.009
	1.25	2889	0.973	1.000	0.991	1.000	0.982	1.000	1.000	1.000	0.991	1.000	0.964	1.000	*1.382*	0.990	0.978	0.990
	1.14	2715	0.995	*1.056*	0.972	1.000	0.967	1.000	0.981	1.000	0.972	1.000	0.981	1.000	*1.486*	*1.056*	0.958	*1.056*
	1.13	2911	0.977	0.972	1.000	1.000	0.986	1.000	1.000	1.000	0.981	1.000	0.977	1.000	*1.394*	0.951	0.977	0.972
stein45	12.80	40723	0.985	0.962	0.995	1.000	0.981	1.000	0.986	1.000	0.979	1.000	0.981	1.000	*1.630*	0.971	0.964	**0.916**
	12.94	39012	0.968	0.995	0.996	1.000	0.984	1.000	0.972	1.000	0.989	1.000	0.972	1.000	*1.698*	0.966	**0.935**	0.976
	13.04	41930	1.000	0.985	0.999	1.000	0.988	1.000	0.994	1.000	0.999	1.000	1.006	1.000	*1.628*	**0.931**	0.994	0.975
	12.20	37543	1.022	1.015	0.993	1.000	1.001	1.000	0.994	1.000	0.992	1.000	0.992	1.000	*1.665*	*1.055*	1.047	1.015
	13.29	40503	0.981	1.006	0.994	1.000	0.978	1.000	0.992	1.000	0.992	1.000	0.999	1.000	*1.666*	0.984	0.985	1.006
tanglegram2	4.09	3	1.004	1.000	1.010	1.000	1.010	1.000	1.012	1.000	1.006	1.000	1.014	1.000	1.026	1.000	1.020	1.000
	3.85	3	1.010	1.000	1.008	1.000	1.010	1.000	1.008	1.000	1.008	1.000	1.002	1.000	1.029	1.000	1.023	1.000
	4.25	3	0.990	1.000	1.000	1.000	0.998	1.000	1.008	1.000	1.008	1.000	1.008	1.000	1.011	1.000	1.023	1.000
	4.11	3	1.002	1.000	1.002	1.000	1.000	1.000	0.992	1.000	0.992	1.000	0.998	1.000	1.016	1.000	1.010	1.000
	4.23	3	0.994	1.000	1.000	1.000	0.985	1.000	0.990	1.000	0.998	1.000	0.994	1.000	1.010	1.000	1.011	1.000

Table C.2: Computational results on `MMM-IP`: Global vs. local, w/ and w/o criteria. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	default		onlyroot				nochecks				degeneracy			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
10teams	2.14	1	2.95	*1.258*	1	1.000	2.92	*1.248*	1	1.000	3.01	*1.277*	1	1.000
	20.00	1367	4.17	**0.246**	5	**0.072**	4.15	**0.245**	5	**0.072**	4.07	**0.241**	5	**0.072**
	15.57	287	10.13	**0.672**	25	**0.323**	21.22	*1.341*	221	**0.829**	25.62	*1.607*	956	*2.729*
	4.16	5	11.02	*2.329*	28	*1.219*	12.98	*2.709*	28	*1.219*	13.04	*2.721*	28	*1.219*
	4.94	5	4.43	**0.914**	5	1.000	4.42	**0.912**	5	1.000	4.40	**0.909**	5	1.000
30n20b8	314.13	195	89.92	**0.289**	2	**0.346**	88.69	**0.285**	2	**0.346**	189.53	**0.605**	63	**0.553**
	157.33	71	133.94	**0.852**	2	**0.596**	123.97	**0.789**	2	**0.596**	111.78	**0.712**	2	**0.596**
	87.25	4	103.86	*1.188*	4	1.000	103.17	*1.180*	2	0.981	87.35	1.001	4	1.000
	213.06	102	266.69	*1.251*	81	**0.896**	223.12	1.047	58	**0.782**	257.61	*1.208*	165	*1.312*
	470.09	290	110.96	**0.238**	65	**0.423**	112.74	**0.241**	64	**0.421**	381.26	**0.811**	182	**0.723**
acc-tight5	125.35	802	139.84	*1.115*	1363	*1.622*	136.33	*1.087*	956	*1.171*	139.72	*1.114*	956	*1.171*
	84.38	508	60.55	**0.721**	479	0.952	152.00	*1.792*	1511	*2.650*	110.82	*1.310*	1160	*2.072*
	50.45	195	168.74	*3.299*	1675	*6.017*	49.10	0.974	174	**0.929**	49.06	0.973	174	**0.929**
	85.88	545	126.22	*1.464*	1120	*1.891*	28.55	**0.340**	22	**0.189**	28.52	**0.340**	22	**0.189**
	73.38	627	92.44	*1.256*	691	*1.088*	30.14	**0.419**	17	**0.161**	30.00	**0.417**	17	**0.161**
air03	1.70	1	16.59	*6.515*	1	1.000	16.37	*6.433*	1	1.000	1.73	1.011	1	1.000
	1.71	1	16.54	*6.472*	1	1.000	16.86	*6.590*	1	1.000	1.72	1.004	1	1.000
	1.74	1	16.46	*6.372*	1	1.000	16.44	*6.365*	1	1.000	1.72	0.993	1	1.000
	1.75	1	16.42	*6.335*	1	1.000	16.54	*6.378*	1	1.000	1.75	1.000	1	1.000
	1.75	1	16.54	*6.378*	1	1.000	16.85	*6.491*	1	1.000	1.74	0.996	1	1.000
air04	49.46	110	44.95	**0.911**	37	**0.652**	48.34	0.978	63	**0.776**	49.60	1.003	110	1.000
	36.09	39	40.26	*1.112*	61	*1.158*	42.47	*1.172*	59	*1.144*	36.38	1.008	39	1.000
	52.88	118	50.14	**0.949**	45	**0.665**	52.50	0.993	45	**0.665**	53.17	1.005	118	1.000
	36.56	31	64.16	*1.735*	301	*3.061*	57.28	*1.552*	94	*1.481*	37.09	1.014	31	1.000
	48.35	122	38.53	**0.801**	11	**0.500**	38.62	**0.803**	11	**0.500**	48.66	1.006	122	1.000
air05	24.82	189	31.78	*1.270*	347	*1.547*	54.12	*2.135*	301	*1.388*	24.56	0.990	189	1.000
	26.54	239	34.12	*1.275*	381	*1.419*	81.79	*3.006*	481	*1.714*	26.64	1.004	239	1.000
	31.37	438	35.65	*1.132*	409	**0.946**	59.50	*1.869*	271	**0.690**	31.10	0.992	438	1.000
	27.36	283	32.31	*1.175*	361	*1.204*	46.63	*1.679*	368	*1.222*	27.57	1.007	283	1.000
	27.14	279	30.74	*1.128*	254	**0.934**	57.64	*2.084*	409	*1.343*	27.23	1.003	279	1.000
blend2	0.69	714	0.76	1.041	714	1.000	0.76	1.041	714	1.000	0.76	1.041	714	1.000
	1.08	973	1.05	0.986	973	1.000	1.10	1.010	973	1.000	1.05	0.986	973	1.000
	1.05	912	1.04	0.995	912	1.000	1.05	1.000	912	1.000	1.06	1.005	912	1.000
	0.67	543	0.70	1.018	543	1.000	0.69	1.012	543	1.000	0.66	0.994	543	1.000
	0.66	709	0.71	1.030	709	1.000	0.70	1.024	709	1.000	0.71	1.030	709	1.000

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Table C.2: Computational results on MMM-IP: Global vs. local, w/ and w/o criteria

	default		onlyroot				nochecks				degeneracy			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
bley_xl1	164.49	1	164.94	1.003	1	1.000	163.94	0.997	1	1.000	163.94	0.997	1	1.000
	187.04	3	169.53	**0.907**	1	0.981	169.30	**0.906**	1	0.981	189.31	1.012	18	*1.146*
	182.51	13	163.79	**0.898**	2	**0.903**	164.30	**0.901**	2	**0.903**	162.64	**0.892**	2	**0.903**
	133.90	1	149.86	*1.118*	1	1.000	131.50	0.982	1	1.000	134.67	1.006	1	1.000
	135.56	1	138.70	1.023	1	1.000	137.46	1.014	1	1.000	136.43	1.006	1	1.000
bnatt350	378.09	3383	798.33	*2.109*	8376	*2.434*	18.77	**0.052**	6	**0.030**	18.90	**0.052**	6	**0.030**
	521.76	4947	253.43	**0.487**	2019	**0.420**	16.38	**0.033**	10	**0.022**	16.29	**0.033**	10	**0.022**
	397.10	4029	352.85	**0.889**	3395	**0.846**	18.02	**0.048**	6	**0.026**	18.02	**0.048**	6	**0.026**
	155.46	1495	701.62	*4.491*	5658	*3.610*	16.14	**0.110**	7	**0.067**	16.08	**0.109**	7	**0.067**
	994.16	10057	314.65	**0.317**	3099	**0.315**	43.44	**0.045**	112	**0.021**	43.21	**0.044**	112	**0.021**
cap6000	2.69	1830	3.05	*1.098*	1571	**0.866**	4.21	*1.412*	2082	*1.131*	2.70	1.003	1830	1.000
	2.67	1837	3.24	*1.155*	2112	*1.142*	4.34	*1.455*	2332	*1.256*	2.62	0.986	1837	1.000
	2.61	1959	3.15	*1.150*	2095	*1.066*	3.62	*1.280*	1922	0.982	2.58	0.992	1959	1.000
	3.17	1924	3.53	*1.086*	1709	**0.894**	4.93	*1.422*	2260	*1.166*	3.20	1.007	1924	1.000
	2.82	1762	3.42	*1.157*	2243	*1.258*	4.30	*1.387*	2367	*1.325*	2.85	1.008	1762	1.000
cov1075	7.74%	1450527	3461.27	0.961	1725170	*1.189*	9.12%	1.000	455101	0.314	3560.96	0.989	1725170	*1.189*
	6.87%	1790225	6.86%	1.000	1769849	0.989	9.19%	1.000	541551	0.303	6.91%	1.000	1745291	0.975
	7.59%	1531529	6.67%	1.000	1853043	1.210	9.18%	1.000	570458	0.373	6.71%	1.000	1834965	1.198
	6.13%	1798178	3589.97	0.997	1789402	0.995	9.11%	1.000	449657	0.250	5.88%	1.000	1771419	0.985
	8.30%	1204894	3524.34	0.979	1824701	*1.514*	9.01%	1.000	554122	0.460	5.26%	1.000	1817274	1.508
csched010	6.88%	237077	3265.17	**0.907**	219274	**0.925**	3.99%	1.000	135299	0.571	6.88%	1.000	237694	1.003
	3.46%	202876	3059.87	**0.850**	210347	1.037	6.79%	1.000	153260	0.756	3.44%	1.000	203138	1.001
	2891.69	177527	5.06%	1.245	227185	1.280	6.96%	1.245	122308	0.689	2893.02	1.000	177527	1.000
	3.65%	238611	4.54%	1.000	245411	1.028	6.15%	1.000	137975	0.578	3.69%	1.000	238053	0.998
	3168.37	173932	4.46%	1.136	227332	1.307	7.47%	1.136	118549	0.682	3171.41	1.001	173932	1.000
eil33-2	69.44	583	76.08	*1.094*	521	**0.909**	123.82	*1.772*	521	**0.909**	69.62	1.003	583	1.000
	81.92	739	84.23	1.028	615	**0.852**	137.59	*1.671*	615	**0.852**	82.52	1.007	739	1.000
	84.87	847	101.60	*1.195*	707	**0.852**	162.47	*1.904*	707	**0.852**	83.95	0.989	847	1.000
	73.60	543	92.97	*1.260*	1654	*2.728*	148.68	*2.006*	870	*1.509*	72.71	0.988	543	1.000
	70.01	583	112.75	*1.602*	867	*1.416*	153.53	*2.176*	879	*1.433*	69.08	0.987	583	1.000
eilB101	378.99	10582	266.81	**0.705**	7632	**0.724**	410.67	*1.083*	7632	**0.724**	378.34	0.998	10582	1.000
	365.27	8427	334.63	**0.916**	8854	*1.050*	508.48	*1.391*	9702	*1.150*	359.35	0.984	8427	1.000
	401.63	9358	328.86	**0.819**	7275	**0.780**	460.62	*1.147*	7275	**0.780**	399.77	0.995	9358	1.000
	397.46	11465	359.54	**0.905**	11753	1.025	518.55	*1.304*	11753	1.025	396.04	0.996	11465	1.000
	365.79	10006	299.04	**0.818**	8939	**0.894**	439.62	*1.201*	8939	**0.894**	361.93	0.989	10006	1.000
enigma	0.50	809	0.50	1.000	678	**0.856**	0.50	1.000	393	**0.542**	0.50	1.000	650	**0.825**
	0.50	449	0.50	1.000	787	*1.616*	0.50	1.000	158	**0.470**	0.50	1.000	173	**0.497**

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Table C.2: Computational results on MMM-IP: Global vs. local, w/ and w/o criteria

Instance	default		onlyroot				nochecks				degeneracy			
	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	541	0.50	1.000	326	**0.665**	0.50	1.000	52	**0.237**	0.50	1.000	63	**0.254**
	0.50	679	0.50	1.000	90	**0.244**	0.50	1.000	18	**0.151**	0.61	*1.073*	318	**0.537**
	0.50	445	0.50	1.000	813	*1.675*	0.52	1.013	196	**0.543**	0.53	1.020	196	**0.543**
enlight13	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
enlight14	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
fiber	1.00	2	1.15	*1.075*	3	1.010	1.32	*1.160*	3	1.010	1.02	1.010	2	1.000
	1.42	4	1.27	**0.938**	3	0.990	2.35	*1.384*	29	*1.240*	1.39	0.988	4	1.000
	1.74	4	1.60	**0.949**	3	0.990	2.84	*1.401*	5	1.010	1.76	1.007	4	1.000
	1.53	4	1.59	1.024	4	1.000	2.02	*1.194*	3	0.990	1.55	1.008	4	1.000
	1.00	3	1.06	1.030	2	0.990	1.16	*1.080*	2	0.990	1.00	1.000	3	1.000
flugpl	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
gt2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
harp2	691.56	1491878	2918.34	*4.215*	7211647	*4.834*	0.00%	5.200	7848217	5.260	694.94	1.005	1491878	1.000
	1159.66	2857677	2689.15	*2.318*	6437063	*2.253*	475.25	**0.410**	652308	**0.228**	1163.82	1.004	2857677	1.000
	336.73	595854	454.31	*1.348*	774583	*1.300*	540.84	*1.604*	733894	*1.232*	333.99	0.992	595854	1.000
	937.54	2046181	998.15	*1.065*	2152624	*1.052*	473.55	**0.506**	655891	**0.321**	934.82	0.997	2046181	1.000
	425.68	923780	3284.84	*7.701*	8061534	*8.726*	1184.94	*2.779*	2025226	*2.192*	433.24	1.018	923780	1.000
iis-100-0-cov	629.92	103302	607.74	0.965	103159	0.999	629.06	0.999	103159	0.999	625.29	0.993	103302	1.000
	545.20	92393	574.12	*1.053*	96689	1.046	615.00	*1.128*	96689	1.046	544.56	0.999	92393	1.000
	520.78	81639	571.59	*1.097*	92102	*1.128*	599.71	*1.151*	92102	*1.128*	520.20	0.999	81639	1.000
	506.53	84800	545.76	*1.077*	91627	*1.080*	565.83	*1.117*	91627	*1.080*	507.53	1.002	84800	1.000

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Table C.2: Computational results on MMM-IP: Global vs. local, w/ and w/o criteria

	default		onlyroot				nochecks				degeneracy			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	544.56	92313	539.36	0.990	97078	*1.052*	593.04	*1.089*	97078	*1.052*	542.59	0.996	92313	1.000
iis-bupa-cov	1915.72	157619	2575.32	*1.344*	216948	*1.376*	3265.98	*1.704*	216948	*1.376*	1917.51	1.001	157619	1.000
	1944.83	164079	2171.99	*1.117*	180262	*1.099*	2448.77	*1.259*	180262	*1.099*	1939.94	0.997	164079	1.000
	1881.83	156888	2033.46	*1.081*	171476	*1.093*	2237.69	*1.189*	171476	*1.093*	1878.21	0.998	156888	1.000
	1959.19	161969	2337.44	*1.193*	199823	*1.234*	2739.98	*1.398*	199823	*1.234*	1938.34	0.989	161969	1.000
	1820.52	158284	2258.64	*1.241*	192893	*1.219*	2509.53	*1.378*	192893	*1.219*	1802.15	0.990	158284	1.000
iis-pima-cov	293.79	4824	298.46	1.016	5360	*1.109*	315.12	*1.072*	5360	*1.109*	292.21	0.995	4824	1.000
	437.19	12189	311.07	**0.712**	5366	**0.445**	325.90	**0.746**	5366	**0.445**	434.93	0.995	12189	1.000
	246.99	4668	299.96	*1.214*	7446	*1.583*	327.83	*1.326*	7446	*1.583*	246.99	1.000	4668	1.000
	284.88	6607	326.04	*1.144*	8382	*1.265*	349.08	*1.225*	8382	*1.265*	285.55	1.002	6607	1.000
	556.78	17821	312.74	**0.562**	6048	**0.343**	330.42	**0.594**	6048	**0.343**	558.43	1.003	17821	1.000
l152lav	5.51	23	5.74	1.035	53	*1.244*	13.83	*2.278*	87	*1.520*	5.47	0.994	23	1.000
	1.67	31	2.27	*1.225*	55	*1.183*	4.69	*2.131*	47	*1.122*	1.63	0.985	31	1.000
	2.93	50	2.78	0.962	45	0.967	10.97	*3.046*	105	*1.367*	2.93	1.000	50	1.000
	2.34	20	3.26	*1.275*	61	*1.342*	11.40	*3.713*	141	*2.008*	2.29	0.985	20	1.000
	3.02	52	2.58	**0.891**	40	**0.921**	7.71	*2.167*	83	*1.204*	3.00	0.995	52	1.000
lectsched-4-obj	27.04	805	26.41	0.978	1355	*1.608*	19.97	**0.748**	95	**0.215**	20.11	**0.753**	95	**0.215**
	23.16	796	23.04	0.995	1049	*1.282*	28.02	*1.201*	158	**0.288**	28.02	*1.201*	158	**0.288**
	86.08	2419	32.44	**0.384**	1653	**0.696**	22.05	**0.265**	205	**0.121**	24.11	**0.288**	565	**0.264**
	26.83	1231	6.15	**0.257**	9	**0.082**	8.18	**0.330**	9	**0.082**	8.09	**0.327**	9	**0.082**
	22.73	745	15.64	**0.701**	447	**0.647**	20.67	**0.913**	114	**0.253**	20.57	**0.909**	114	**0.253**
lseu	0.75	268	0.76	1.006	263	0.986	1.74	*1.566*	303	*1.095*	0.77	1.011	268	1.000
	0.50	4	0.50	1.000	4	1.000	0.50	1.000	5	1.010	0.50	1.000	4	1.000
	0.51	205	0.50	0.993	184	**0.931**	0.87	*1.238*	164	**0.866**	0.50	0.993	205	1.000
	0.50	91	0.50	1.000	85	0.969	0.50	1.000	41	**0.738**	0.50	1.000	91	1.000
	0.50	191	0.50	1.000	98	**0.680**	1.07	*1.380*	95	**0.670**	0.51	1.007	191	1.000
m100n500k4r1	4.17%	2170459	4.17%	1.000	2542431	1.171	4.17%	1.000	1692600	0.780	4.17%	1.000	2426435	1.118
	4.17%	2278212	4.17%	1.000	2413627	1.059	4.17%	1.000	1780742	0.782	4.17%	1.000	2358830	1.035
	4.17%	2617105	4.17%	1.000	2434209	0.930	4.17%	1.000	1463995	0.559	4.17%	1.000	2313256	0.884
	4.17%	2309660	4.17%	1.000	2283320	0.989	4.17%	1.000	1478318	0.640	4.17%	1.000	2163125	0.937
	4.17%	2245563	4.17%	1.000	2071678	0.923	4.17%	1.000	1448404	0.645	4.17%	1.000	1871050	0.833
macrophage	125.50	5163	114.29	**0.911**	3588	**0.701**	223.41	*1.774*	5996	*1.158*	125.68	1.001	5163	1.000
	157.18	7241	148.93	**0.948**	6155	**0.852**	241.86	*1.535*	8591	*1.184*	157.07	0.999	7241	1.000
	209.11	9131	171.43	**0.821**	9624	*1.053*	301.06	*1.438*	11443	*1.250*	209.04	1.000	9131	1.000
	162.53	7927	176.09	*1.083*	6641	**0.840**	305.78	*1.876*	8634	*1.088*	162.46	1.000	7927	1.000
	121.37	5239	128.54	*1.059*	5619	*1.071*	242.09	*1.987*	7133	*1.355*	121.23	0.999	5239	1.000

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Table C.2: Computational results on MMM-IP: Global vs. local, w/ and w/o criteria

	default		onlyroot				nochecks				degeneracy			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
manna81	0.50	1	0.53	1.020	1	1.000	0.51	1.007	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.52	1.013	1	1.000	0.52	1.013	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.55	1.033	1	1.000	0.52	1.013	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.52	1.013	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.55	1.033	1	1.000	0.51	1.007	1	1.000	0.50	1.000	1	1.000
markshare1	∞	19093205	∞	1.000	20684843	1.083	∞	1.000	17648464	0.924	∞	1.000	17773362	0.931
	∞	20203360	∞	1.000	20552913	1.017	∞	1.000	17296421	0.856	∞	1.000	17405834	0.862
	∞	19520584	∞	1.000	23790351	1.219	∞	1.000	17927482	0.918	∞	1.000	17945211	0.919
	∞	20427204	∞	1.000	20766538	1.017	∞	1.000	18450265	0.903	∞	1.000	18348094	0.898
	∞	21513467	∞	1.000	23454252	1.090	∞	1.000	17098493	0.795	∞	1.000	17151823	0.797
markshare2	∞	4072360	∞	1.000	3900069	0.958	∞	1.000	3446102	0.846	∞	1.000	3433363	0.843
	∞	5640455	∞	1.000	3585353	0.636	∞	1.000	3933991	0.697	∞	1.000	3929356	0.697
	∞	3582521	∞	1.000	3880990	1.083	∞	1.000	3675467	1.026	∞	1.000	3675025	1.026
	∞	4239467	∞	1.000	3778524	0.891	∞	1.000	4531397	1.069	∞	1.000	4532415	1.069
	∞	5142521	∞	1.000	4873811	0.948	∞	1.000	4278067	0.832	∞	1.000	4267105	0.830
mcsched	285.92	13689	234.16	**0.820**	9995	**0.732**	312.71	*1.093*	9253	**0.678**	285.70	0.999	13689	1.000
	271.88	11373	397.23	*1.459*	19521	*1.710*	871.12	*3.196*	19947	*1.747*	271.59	0.999	11373	1.000
	233.97	10059	301.42	*1.287*	13204	*1.310*	578.96	*2.468*	13070	*1.296*	233.00	0.996	10059	1.000
	286.25	12496	301.99	*1.055*	14336	*1.146*	702.67	*2.450*	15581	*1.245*	285.38	0.997	12496	1.000
	270.69	10373	272.70	1.007	10285	0.992	417.87	*1.542*	10328	0.996	272.13	1.005	10373	1.000
mine-166-5	58.69	1569	49.77	**0.851**	3838	*2.359*	45.29	**0.776**	1605	1.022	58.40	0.995	1569	1.000
	57.78	1191	64.23	*1.110*	1063	**0.901**	53.09	**0.920**	1100	**0.930**	57.21	0.990	1191	1.000
	46.45	2244	52.72	*1.132*	1423	**0.650**	51.36	*1.103*	2402	*1.067*	46.49	1.001	2244	1.000
	64.93	139	39.82	**0.619**	1457	*6.515*	45.90	**0.711**	1190	*5.397*	65.30	1.006	139	1.000
	42.28	2863	42.00	0.994	2486	**0.873**	49.43	*1.165*	1545	**0.555**	42.28	1.000	2863	1.000
mine-90-10	276.07	47643	211.45	**0.767**	28333	**0.596**	285.11	1.033	35706	**0.750**	276.51	1.002	47643	1.000
	125.32	22195	219.88	*1.749*	31967	*1.438*	586.61	*4.652*	81510	*3.660*	125.11	0.998	22195	1.000
	173.25	25979	473.85	*2.725*	58954	*2.264*	292.88	*1.687*	27531	*1.060*	173.38	1.001	25979	1.000
	500.83	87496	277.87	**0.556**	39905	**0.457**	405.10	**0.809**	40071	**0.459**	502.57	1.003	87496	1.000
	236.18	32520	179.80	**0.762**	19201	**0.592**	511.68	*2.162*	57542	*1.767*	237.48	1.005	32520	1.000
misc03	1.39	398	0.70	**0.711**	31	**0.263**	0.91	**0.799**	33	**0.267**	1.40	1.004	398	1.000
	0.71	15	0.87	*1.094*	41	*1.226*	1.44	*1.427*	41	*1.226*	0.71	1.000	15	1.000
	0.70	19	1.00	*1.176*	77	*1.487*	1.57	*1.512*	75	*1.471*	0.73	1.018	19	1.000
	1.00	111	0.71	**0.855**	49	**0.706**	1.03	1.015	61	**0.763**	0.98	0.990	111	1.000
	0.66	15	0.91	*1.151*	85	*1.609*	1.67	*1.608*	65	*1.435*	0.64	0.988	15	1.000
misc07	38.05	28289	41.43	*1.087*	33627	*1.188*	57.41	*1.496*	21427	**0.758**	38.28	1.006	28289	1.000
	36.66	29782	34.62	**0.946**	32173	*1.080*	80.98	*2.177*	30291	1.017	36.49	0.995	29782	1.000

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Table C.2: Computational results on MMM-IP: Global vs. local, w/ and w/o criteria

	default		onlyroot				nochecks				degeneracy			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	21.56	17632	50.31	*2.274*	41266	*2.333*	81.56	*3.660*	28239	*1.598*	21.45	0.995	17632	1.000
	45.95	38975	37.13	**0.812**	31384	**0.806**	61.93	*1.340*	22889	**0.588**	45.80	0.997	38975	1.000
	30.94	29476	33.62	*1.084*	27612	**0.937**	39.45	*1.266*	16362	**0.557**	30.56	0.988	29476	1.000
mitre	10.20	1	14.39	*1.374*	1	1.000	14.47	*1.381*	1	1.000	14.57	*1.390*	1	1.000
	10.28	1	15.42	*1.456*	1	1.000	15.35	*1.449*	1	1.000	15.57	*1.469*	1	1.000
	10.94	1	16.28	*1.447*	1	1.000	15.58	*1.389*	1	1.000	15.52	*1.384*	1	1.000
	10.45	1	15.03	*1.400*	1	1.000	15.00	*1.397*	1	1.000	15.17	*1.412*	1	1.000
	13.12	1	13.90	*1.055*	1	1.000	13.77	1.046	1	1.000	13.39	1.019	1	1.000
mod008	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.54	2	0.59	1.032	2	1.000	0.58	1.026	2	1.000	0.53	0.994	2	1.000
	0.52	2	0.55	1.020	1	0.990	0.56	1.026	1	0.990	0.54	1.013	2	1.000
	0.52	1	0.57	1.033	1	1.000	0.55	1.020	1	1.000	0.51	0.993	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
mod010	0.50	2	0.91	*1.273*	2	1.000	1.19	*1.460*	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.77	*1.180*	1	1.000	0.79	*1.193*	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.91	*1.273*	2	1.010	0.85	*1.233*	2	1.010	0.50	1.000	1	1.000
	0.52	2	0.82	*1.197*	2	1.000	1.02	*1.329*	2	1.000	0.53	1.007	2	1.000
	0.50	1	0.98	*1.320*	2	1.010	1.02	*1.347*	2	1.010	0.50	1.000	1	1.000
mzzv11	332.43	2022	309.78	**0.932**	601	**0.330**	495.90	*1.490*	1137	**0.583**	332.03	0.999	2022	1.000
	229.41	959	361.33	*1.573*	1192	*1.220*	333.89	*1.453*	766	**0.818**	229.82	1.002	959	1.000
	310.05	1421	364.42	*1.175*	698	**0.525**	282.16	**0.910**	531	**0.415**	311.22	1.004	1421	1.000
	327.03	1579	315.36	0.964	558	**0.392**	327.01	1.000	535	**0.378**	322.67	0.987	1579	1.000
	186.14	627	271.91	*1.458*	460	**0.770**	325.82	*1.746*	475	**0.791**	186.23	1.000	627	1.000
mzzv42z	152.40	265	149.99	0.984	175	**0.753**	319.04	*2.086*	439	*1.477*	151.11	0.992	265	1.000
	131.25	125	222.82	*1.692*	275	*1.667*	276.15	*2.096*	268	*1.636*	131.14	0.999	125	1.000
	197.62	200	284.19	*1.436*	235	*1.117*	448.29	*2.262*	379	*1.597*	198.89	1.006	200	1.000
	213.83	456	359.28	*1.677*	438	0.968	322.04	*1.504*	370	**0.845**	214.35	1.002	456	1.000
	167.65	300	191.72	*1.143*	178	**0.695**	226.18	*1.347*	163	**0.657**	167.53	0.999	300	1.000
neos-1109824	37.52	1796	58.84	*1.553*	4938	*2.657*	81.97	*2.154*	4158	*2.246*	37.38	0.996	1796	1.000
	46.67	3438	45.18	0.969	3303	0.962	61.92	*1.320*	2766	**0.810**	46.57	0.998	3438	1.000
	35.16	1913	48.63	*1.373*	3737	*1.906*	52.45	*1.478*	1906	0.997	34.97	0.995	1913	1.000
	77.65	8290	53.63	**0.695**	4382	**0.534**	76.40	0.984	3634	**0.445**	77.32	0.996	8290	1.000
	39.64	2247	44.51	*1.120*	2428	*1.077*	77.29	*1.926*	3529	*1.546*	39.22	0.990	2247	1.000
neos-1337307	0.04%	302483	0.03%	1.000	345309	1.142	0.11%	1.000	50500	0.167	0.04%	1.000	306352	1.013
	0.06%	269510	0.08%	1.000	225574	0.837	0.11%	1.000	45548	0.169	0.06%	1.000	269284	0.999
	0.04%	348643	0.02%	1.000	383798	1.101	0.09%	1.000	53421	0.153	0.04%	1.000	349832	1.003
	0.06%	300587	0.04%	1.000	337763	1.124	0.12%	1.000	45535	0.152	0.06%	1.000	301363	1.003

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Table C.2: Computational results on MMM-IP: Global vs. local, w/ and w/o criteria

	default		onlyroot				nochecks				degeneracy			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.03%	367746	0.03%	1.000	362606	0.986	0.11%	1.000	40940	0.112	0.03%	1.000	373217	1.015
neos-1601936	2034.60	1453	433.33%	1.769	955	0.679	100.00%	1.769	1765	1.201	2033.50	0.999	1453	1.000
	666.67%	2849	100.00%	1.000	1697	0.609	233.33%	1.000	951	0.356	666.67%	1.000	2861	1.004
	1348.55	2661	≥ 10000%	2.668	1357	0.528	4433.33%	2.668	1395	0.541	1338.93	0.993	2661	1.000
	100.00%	6919	3232.94	**0.898**	1007	**0.158**	100.00%	1.000	5731	0.831	100.00%	1.000	6917	1.000
	533.33%	6139	1500.11	**0.417**	997	**0.176**	1000.00%	1.000	2650	0.441	533.33%	1.000	6139	1.000
neos-686190	83.42	4906	142.80	*1.703*	11748	*2.367*	638.83	*7.579*	16907	*3.397*	83.27	0.998	4906	1.000
	86.19	6047	379.69	*4.366*	39812	*6.493*	754.95	*8.670*	20843	*3.407*	86.55	1.004	6047	1.000
	114.74	9156	84.20	**0.736**	5752	**0.632**	432.12	*3.742*	5928	**0.651**	115.34	1.005	9156	1.000
	116.53	9998	79.08	**0.681**	5592	**0.564**	381.54	*3.255*	4549	**0.460**	117.19	1.006	9998	1.000
	121.04	9806	75.51	**0.627**	5571	**0.572**	302.16	*2.484*	4785	**0.493**	120.84	0.998	9806	1.000
neos-849702	114.99	2031	1112.62	*9.601*	25170	*11.858*	207.98	*1.802*	1169	**0.595**	207.98	*1.802*	1169	**0.595**
	353.12	17540	1001.02	*2.830*	36663	*2.084*	1032.62	*2.919*	6328	**0.364**	1025.85	*2.900*	6328	**0.364**
	357.57	29405	756.02	*2.111*	2262	**0.080**	1002.48	*2.799*	10499	**0.359**	1001.35	*2.795*	10499	**0.359**
	261.49	16226	1316.55	*5.019*	17876	*1.101*	267.40	1.023	683	**0.048**	267.07	1.021	683	**0.048**
	143.57	4968	763.03	*5.285*	27217	*5.390*	285.18	*1.980*	1596	**0.335**	285.44	*1.981*	1596	**0.335**
neos-934278	1.35%	1184	8.29%	1.000	336	0.340	8.29%	1.000	330	0.335	1.35%	1.000	1175	0.993
	428.32%	265	797.50%	1.000	321	1.153	797.50%	1.000	302	1.101	428.32%	1.000	267	1.005
	828.32%	263	777.84%	1.000	329	1.182	777.84%	1.000	308	1.124	828.32%	1.000	263	1.000
	416.76%	391	40.66%	1.000	321	0.857	40.66%	1.000	310	0.835	416.76%	1.000	401	1.020
	8.67%	521	7.90%	1.000	345	0.717	7.90%	1.000	322	0.680	8.67%	1.000	522	1.002
neos18	24.17	1378	22.03	**0.915**	1257	**0.918**	7.92	**0.354**	79	**0.121**	8.13	**0.363**	79	**0.121**
	21.26	1321	21.96	1.031	1934	*1.431*	20.52	0.967	563	**0.467**	24.87	*1.162*	828	**0.653**
	23.36	1646	21.27	**0.914**	1338	**0.824**	28.68	*1.218*	1095	**0.684**	28.94	*1.229*	1095	**0.684**
	19.21	996	20.41	*1.059*	1096	*1.091*	15.36	**0.810**	386	**0.443**	15.42	**0.812**	386	**0.443**
	22.07	1049	26.09	*1.174*	2252	*2.047*	20.88	**0.948**	813	**0.795**	21.77	0.987	963	**0.925**
ns1208400	2439.01	14168	1174.95	**0.482**	5666	**0.404**	1182.58	**0.485**	3763	**0.271**	938.01	**0.385**	3025	**0.219**
	1985.63	7882	964.93	**0.486**	2936	**0.380**	2759.45	*1.390*	11477	*1.450*	2737.49	*1.378*	11477	*1.450*
	1467.85	5026	988.10	**0.673**	3835	**0.768**	537.42	**0.367**	1719	**0.355**	532.73	**0.363**	1719	**0.355**
	∞	5611	528.45	**0.147**	2183	**0.400**	253.31	**0.071**	599	**0.122**	253.07	**0.071**	599	**0.122**
	2388.79	8711	1273.64	**0.533**	5684	**0.656**	120.01	**0.051**	495	**0.068**	1316.58	**0.551**	2660	**0.313**
ns1688347	55.09	451	57.24	1.038	415	**0.935**	55.03	0.999	508	*1.103*	51.67	**0.939**	437	0.975
	45.64	485	64.10	*1.396*	831	*1.591*	48.33	*1.058*	391	**0.839**	42.42	**0.931**	203	**0.518**
	106.90	1865	160.04	*1.492*	2336	*1.240*	94.36	**0.884**	1022	**0.571**	161.82	*1.509*	3095	*1.626*
	139.57	1219	107.32	**0.771**	559	**0.500**	94.90	**0.682**	334	**0.329**	133.50	0.957	1251	1.024
	55.82	745	65.42	*1.169*	951	*1.244*	47.30	**0.850**	365	**0.550**	51.48	**0.924**	399	**0.591**

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Table C.2: Computational results on MMM-IP: Global vs. local, w/ and w/o criteria

Instance	default T	default N	onlyroot T	onlyroot T_Q	onlyroot N	onlyroot N_Q	nochecks T	nochecks T_Q	nochecks N	nochecks N_Q	degeneracy T	degeneracy T_Q	degeneracy N	degeneracy N_Q
ns1830653	132.81	6918	150.42	*1.132*	7113	1.028	151.76	*1.142*	4554	**0.663**	133.08	1.002	6918	1.000
	123.49	5226	151.30	*1.223*	6742	*1.285*	191.76	*1.548*	5932	*1.133*	123.87	1.003	5226	1.000
	161.13	9597	176.18	*1.093*	9448	0.985	198.19	*1.229*	4544	**0.479**	161.00	0.999	9597	1.000
	143.05	7435	158.02	*1.104*	8770	*1.177*	170.82	*1.193*	6174	**0.833**	143.21	1.001	7435	1.000
	146.20	9194	170.07	*1.162*	6759	**0.738**	150.38	1.028	3671	**0.406**	146.08	0.999	9194	1.000
nsrand-ipx	422.05	50124	801.32	*1.897*	94904	*1.892*	2675.56	*6.327*	46997	**0.938**	419.85	0.995	50124	1.000
	643.65	86869	323.35	**0.503**	32760	**0.378**	2747.02	*4.263*	77408	**0.891**	638.54	0.992	86869	1.000
	568.28	56575	625.86	*1.101*	57477	1.016	1.95%	6.326	40437	0.715	569.66	1.002	56575	1.000
	582.50	61056	523.27	**0.898**	54502	**0.893**	3055.08	*5.237*	68534	*1.122*	582.34	1.000	61056	1.000
	367.03	38012	686.21	*1.867*	79493	*2.088*	3460.39	*9.405*	74535	*1.958*	363.56	0.991	38012	1.000
opt1217	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
p0033	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
p0201	0.55	5	0.50	0.968	11	*1.057*	0.50	0.968	11	*1.057*	0.54	0.994	5	1.000
	0.71	9	0.58	**0.924**	7	0.982	0.58	**0.924**	7	0.982	0.74	1.018	9	1.000
	1.59	5	1.12	**0.819**	154	*2.419*	0.94	**0.749**	27	*1.210*	1.64	1.019	5	1.000
	0.90	13	0.73	**0.911**	23	*1.088*	1.01	*1.058*	23	*1.088*	0.90	1.000	13	1.000
	0.91	59	0.55	**0.812**	21	**0.761**	0.70	**0.890**	21	**0.761**	0.89	0.990	59	1.000
p0282	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	3	0.55	1.033	3	1.000	0.50	1.000	2	0.990	0.50	1.000	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000	0.50	1.000	2	1.000
p0548	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000	0.50	1.000	1	1.000
p2756	2.46	5	1.98	**0.861**	4	0.990	2.26	**0.942**	12	*1.067*	2.51	1.014	5	1.000
	3.33	5	3.32	0.998	4	0.990	3.77	*1.102*	6	1.010	3.33	1.000	5	1.000

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Table C.2: Computational results on MMM-IP: Global vs. local, w/ and w/o criteria

	default		onlyroot				nochecks				degeneracy			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	2.16	3	2.10	0.981	3	1.000	2.39	*1.073*	4	1.010	2.13	0.991	3	1.000
	2.60	3	2.47	0.964	5	1.019	2.49	0.969	4	1.010	2.54	0.983	3	1.000
	1.22	2	1.36	*1.063*	3	1.010	1.39	*1.077*	3	1.010	1.28	1.027	2	1.000
protfold	130.48%	4783	129.45%	1.000	2488	0.530	59.85%	1.000	2707	0.575	47.20%	1.000	3244	0.685
	55.79%	8172	105.59%	1.000	2294	0.289	61.14%	1.000	2406	0.303	94.74%	1.000	2504	0.315
	77.25%	5838	60.10%	1.000	2025	0.358	54.43%	1.000	3216	0.558	61.08%	1.000	2755	0.481
	42.42%	7263	104.31%	1.000	1598	0.231	47.61%	1.000	1843	0.264	52.97%	1.000	1831	0.262
	149.24%	5620	75.37%	1.000	1610	0.299	69.52%	1.000	2273	0.415	75.95%	1.000	1867	0.344
pw-myciel4	25.00%	519843	25.00%	1.000	451313	0.868	20.88%	1.000	565243	1.087	25.00%	1.000	361131	0.695
	11.11%	443116	25.00%	1.000	460663	1.040	42.86%	1.000	281619	0.636	50.44%	1.000	365865	0.826
	42.86%	391642	37.17%	1.000	356479	0.910	42.86%	1.000	305440	0.780	42.86%	1.000	323450	0.826
	2920.77	395762	25.00%	1.232	389597	0.984	25.00%	1.232	445421	1.125	25.00%	1.232	358151	0.905
	21.69%	405235	42.86%	1.000	487774	1.204	3495.63	0.971	338040	**0.834**	3054.26	**0.848**	378549	**0.934**
qnet1	4.52	33	1.51	**0.455**	6	**0.797**	1.51	**0.455**	6	**0.797**	4.54	1.004	33	1.000
	3.09	3	2.29	**0.804**	3	1.000	3.44	*1.086*	2	0.990	3.12	1.007	3	1.000
	3.94	29	3.69	**0.949**	29	1.000	4.62	*1.138*	29	1.000	3.92	0.996	29	1.000
	2.23	3	2.46	*1.071*	4	1.010	2.75	*1.161*	12	*1.087*	2.26	1.009	3	1.000
	3.69	34	3.16	**0.887**	37	1.022	4.62	*1.198*	30	0.970	3.71	1.004	34	1.000
qnet1_o	3.93	27	3.12	**0.836**	18	**0.929**	3.53	**0.919**	18	**0.929**	3.87	0.988	27	1.000
	3.35	24	2.90	**0.897**	23	0.992	3.76	*1.094*	23	0.992	3.38	1.007	24	1.000
	3.37	15	1.69	**0.616**	2	**0.887**	2.11	**0.712**	4	**0.904**	3.39	1.005	15	1.000
	1.66	2	1.65	0.996	2	1.000	2.04	*1.143*	2	1.000	1.67	1.004	2	1.000
	1.83	3	1.88	1.018	3	1.000	2.07	*1.085*	3	1.000	1.84	1.004	3	1.000
reblock67	222.59	49530	178.55	**0.803**	29575	**0.598**	602.91	*2.701*	60687	*1.225*	223.13	1.002	49530	1.000
	161.89	40625	206.12	*1.272*	49354	*1.214*	368.79	*2.270*	38304	**0.943**	161.91	1.000	40625	1.000
	194.41	49882	175.26	**0.902**	43701	**0.876**	427.20	*2.191*	47444	0.951	194.68	1.001	49882	1.000
	199.06	50996	172.68	**0.868**	39109	**0.767**	670.17	*3.355*	83613	*1.638*	200.17	1.006	50996	1.000
	239.84	57566	171.43	**0.716**	45727	**0.795**	410.05	*1.707*	67395	*1.170*	239.14	0.997	57566	1.000
rmine6	971.86	111047	1401.08	*1.441*	100564	**0.906**	1675.99	*1.724*	118562	*1.068*	971.59	1.000	111047	1.000
	883.48	89213	835.01	**0.945**	82150	**0.921**	1988.32	*2.249*	140483	*1.574*	882.29	0.999	89213	1.000
	775.32	91530	804.33	1.037	92833	1.014	1621.31	*2.090*	116087	*1.268*	776.69	1.002	91530	1.000
	740.58	85429	970.58	*1.310*	91620	*1.072*	1346.60	*1.817*	106768	*1.249*	742.25	1.002	85429	1.000
	771.48	76017	874.88	*1.134*	86994	*1.144*	1220.17	*1.581*	88795	*1.168*	773.39	1.002	76017	1.000
rococoC10-001000	601.83	46983	1320.41	*2.192*	85436	*1.817*	1424.44	*2.365*	89279	*1.898*	603.64	1.003	46983	1.000
	833.40	75156	1400.00	*1.679*	103539	*1.377*	2002.61	*2.401*	113457	*1.509*	836.01	1.003	75156	1.000
	517.62	37178	739.36	*1.428*	54236	*1.458*	969.80	*1.872*	63627	*1.710*	516.72	0.998	37178	1.000
	892.04	51410	959.66	*1.076*	69152	*1.344*	1550.46	*1.737*	102611	*1.994*	893.05	1.001	51410	1.000

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Table C.2: Computational results on MMM-IP: Global vs. local, w/ and w/o criteria

	default		onlyroot				nochecks				degeneracy			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1047.39	66016	1432.47	*1.367*	94701	*1.434*	2363.20	*2.255*	123101	*1.863*	1048.40	1.001	66016	1.000
seymour	0.82%	102645	0.94%	1.000	78822	0.768	0.96%	1.000	73602	0.717	0.82%	1.000	102192	0.996
	0.76%	120322	1.12%	1.000	78925	0.656	1.13%	1.000	75292	0.626	0.76%	1.000	120186	0.999
	0.81%	122337	0.91%	1.000	96723	0.791	0.93%	1.000	90147	0.737	0.81%	1.000	123015	1.006
	0.84%	107537	0.96%	1.000	101351	0.943	0.98%	1.000	89907	0.836	0.84%	1.000	108085	1.005
	0.89%	96726	1.00%	1.000	103365	1.069	1.02%	1.000	96937	1.002	0.89%	1.000	97046	1.003
sp98ir	57.90	3948	95.39	*1.637*	5839	*1.467*	174.51	*2.980*	5385	*1.355*	58.06	1.003	3948	1.000
	65.87	4178	73.58	*1.115*	4796	*1.144*	161.34	*2.428*	5291	*1.260*	65.95	1.001	4178	1.000
	67.64	4735	88.67	*1.306*	5937	*1.249*	208.76	*3.056*	6463	*1.357*	67.93	1.004	4735	1.000
	72.68	4603	64.61	**0.890**	4046	**0.882**	166.59	*2.275*	4097	**0.892**	72.47	0.997	4603	1.000
	70.05	4780	76.28	*1.088*	5991	*1.248*	148.81	*2.109*	5436	*1.134*	69.87	0.997	4780	1.000
stein27	1.12	2749	1.32	*1.094*	2981	*1.081*	2.16	*1.491*	2981	*1.081*	1.17	1.024	2749	1.000
	1.19	2699	1.22	1.014	2725	1.009	2.29	*1.502*	2769	1.025	1.23	1.018	2699	1.000
	1.25	2889	1.20	0.978	2859	0.990	2.11	*1.382*	2859	0.990	1.19	0.973	2889	1.000
	1.14	2715	1.05	0.958	2873	*1.056*	2.18	*1.486*	2873	*1.056*	1.13	0.995	2873	*1.056*
	1.13	2911	1.08	0.977	2827	0.972	1.97	*1.394*	2763	0.951	1.08	0.977	2827	0.972
stein45	12.80	40723	12.30	0.964	37310	**0.916**	21.50	*1.630*	39556	0.971	12.59	0.985	39175	0.962
	12.94	39012	12.04	**0.935**	38089	0.976	22.67	*1.698*	37665	0.966	12.49	0.968	38805	0.995
	13.04	41930	12.96	0.994	40863	0.975	21.86	*1.628*	39024	**0.931**	13.04	1.000	41279	0.985
	12.20	37543	12.82	1.047	38104	1.015	20.98	*1.665*	39632	*1.055*	12.49	1.022	38104	1.015
	13.29	40503	13.08	0.985	40755	1.006	22.80	*1.666*	39866	0.984	13.02	0.981	40755	1.006
tanglegram2	4.09	3	4.19	1.020	3	1.000	4.22	1.026	3	1.000	4.11	1.004	3	1.000
	3.85	3	3.96	1.023	3	1.000	3.99	1.029	3	1.000	3.90	1.010	3	1.000
	4.25	3	4.37	1.023	3	1.000	4.31	1.011	3	1.000	4.20	0.990	3	1.000
	4.11	3	4.16	1.010	3	1.000	4.19	1.016	3	1.000	4.12	1.002	3	1.000
	4.23	3	4.29	1.011	3	1.000	4.28	1.010	3	1.000	4.20	0.994	3	1.000

Table C.3: Computational results on MMM-IP: Impact of combined criteria. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	default		degeneracy + leaves		leaves + obj		all6criterion	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
10teams	2.14	1	*1.293*	1.000	1.022	1.000	*1.248*	1.000
	20.00	1367	**0.244**	**0.072**	*1.230*	1.001	**0.246**	**0.072**
	15.57	287	*1.636*	*2.729*	0.998	1.000	*1.508*	*1.835*
	4.16	5	*2.723*	*1.219*	1.006	1.000	*2.725*	*1.219*
	4.94	5	**0.912**	1.000	1.012	1.000	**0.911**	1.000
30n20b8	314.13	195	**0.604**	**0.553**	0.992	1.000	**0.344**	**0.346**
	157.33	71	**0.711**	**0.596**	1.000	1.000	**0.808**	**0.596**
	87.25	4	1.001	1.000	0.997	1.000	*1.193*	1.000
	213.06	102	*1.202*	*1.312*	0.976	0.950	1.048	**0.782**
	470.09	290	**0.813**	**0.723**	1.004	1.000	**0.243**	**0.421**
acc-tight5	125.35	802	*1.093*	*1.171*	**0.426**	**0.302**	*1.087*	*1.171*
	84.38	508	*1.786*	*2.650*	**0.426**	**0.252**	*1.790*	*2.650*
	50.45	195	0.974	**0.929**	*1.740*	*1.966*	0.978	**0.929**
	85.88	545	**0.339**	**0.189**	**0.420**	**0.274**	**0.343**	**0.189**
	73.38	627	**0.418**	**0.161**	*1.969*	*2.048*	**0.418**	**0.161**
air03	1.70	1	1.037	1.000	1.037	1.000	1.007	1.000
	1.71	1	1.004	1.000	1.007	1.000	1.004	1.000
	1.74	1	0.996	1.000	1.004	1.000	0.993	1.000
	1.75	1	1.000	1.000	0.993	1.000	1.002	1.000
	1.75	1	1.000	1.000	1.000	1.000	0.996	1.000
air04	49.46	110	1.015	1.000	1.003	1.000	1.007	1.000
	36.09	39	1.005	1.000	0.999	1.000	1.003	1.000
	52.88	118	0.997	1.000	0.999	1.000	0.989	1.000
	36.56	31	1.010	1.000	1.015	1.000	1.001	1.000
	48.35	122	0.998	1.000	1.007	1.000	1.001	1.000
air05	24.82	189	0.997	1.000	1.001	1.000	0.991	1.000
	26.54	239	1.004	1.000	1.001	1.000	1.009	1.000
	31.37	438	1.001	1.000	1.000	1.000	0.997	1.000
	27.36	283	1.005	1.000	1.004	1.000	1.010	1.000
	27.14	279	1.001	1.000	0.999	1.000	1.000	1.000
blend2	0.69	714	1.036	1.000	1.047	1.000	1.036	1.000
	1.08	973	0.995	1.000	1.010	1.000	1.010	1.000
	1.05	912	1.000	1.000	0.985	1.000	0.990	1.000
	0.67	543	0.982	1.000	1.000	1.000	1.006	1.000
	0.66	709	1.042	1.000	1.048	1.000	1.042	1.000
bley_xl1	164.49	1	1.009	1.000	1.000	1.000	1.007	1.000
	187.04	3	1.013	*1.146*	1.007	1.000	1.017	*1.146*
	182.51	13	**0.887**	**0.903**	1.006	1.000	**0.896**	**0.903**
	133.90	1	1.002	1.000	1.011	1.000	1.004	1.000
	135.56	1	1.012	1.000	1.008	1.000	1.007	1.000
bnatt350	378.09	3383	**0.052**	**0.030**	**0.107**	**0.054**	**0.052**	**0.030**
	521.76	4947	**0.033**	**0.022**	**0.292**	**0.147**	**0.033**	**0.022**
	397.10	4029	**0.047**	**0.026**	**0.123**	**0.053**	**0.048**	**0.026**
	155.46	1495	**0.109**	**0.067**	*2.608*	*2.974*	**0.109**	**0.067**
	994.16	10057	**0.044**	**0.021**	**0.330**	**0.259**	**0.044**	**0.021**
cap6000	2.69	1830	1.011	1.000	1.011	1.000	0.997	1.000
	2.67	1837	0.995	1.000	0.995	1.000	1.000	1.000
	2.61	1959	0.994	1.000	1.017	1.000	1.014	1.000
	3.17	1924	1.005	1.000	1.000	1.000	0.998	1.000
	2.82	1762	1.008	1.000	1.005	1.000	0.997	1.000
cov1075	3600.00	1450527	0.991	*1.189*	1.000	0.996	0.991	*1.189*
	3600.00	1790225	1.000	0.974	1.000	1.002	1.000	0.978
	3600.00	1531529	1.000	*1.179*	1.000	1.000	1.000	*1.151*
	3600.00	1798178	1.000	0.984	1.000	1.008	1.000	0.984
	3600.00	1204894	1.000	*1.507*	1.000	0.998	1.000	*1.505*
csched010	3600.00	237077	1.000	0.961	1.000	0.963	**0.812**	**0.726**
	3600.00	202876	1.000	**0.863**	1.000	**0.861**	1.000	*1.145*
	2891.69	177527	*1.145*	*1.206*	*1.144*	*1.206*	*1.245*	*1.177*
	3600.00	238611	0.989	**0.820**	0.986	**0.820**	1.000	**0.927**
	3168.37	173932	*1.136*	*1.300*	*1.136*	*1.304*	*1.136*	*1.369*

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Table C.3: Computational results on MMM-IP: Impact of combined criteria.

	default		degeneracy + leaves		leaves + obj		all6criterion	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
eil33-2	69.44	583	1.013	1.000	1.007	1.000	1.006	1.000
	81.92	739	1.000	1.000	0.998	1.000	1.003	1.000
	84.87	847	1.004	1.000	1.005	1.000	1.001	1.000
	73.60	543	1.005	1.000	1.003	1.000	1.005	1.000
	70.01	583	1.001	1.000	1.001	1.000	0.999	1.000
eilB101	378.99	10582	1.002	1.000	1.015	1.000	0.993	1.000
	365.27	8427	0.994	1.000	0.994	1.000	0.996	1.000
	401.63	9358	1.004	1.000	0.996	1.000	1.004	1.000
	397.46	11465	1.000	1.000	1.000	1.000	1.001	1.000
	365.79	10006	1.005	1.000	0.997	1.000	0.999	1.000
enigma	0.50	809	1.000	**0.825**	1.000	0.998	1.000	**0.542**
	0.50	449	1.000	**0.497**	1.000	1.000	1.000	**0.470**
	0.50	541	1.000	**0.254**	1.000	0.977	1.000	**0.237**
	0.50	679	*1.060*	**0.537**	1.000	1.000	1.000	**0.151**
	0.50	445	1.000	**0.543**	1.000	1.006	1.033	**0.543**
enlight13	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
enlight14	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
fiber	1.00	2	1.005	1.000	1.025	1.000	1.005	1.000
	1.42	4	1.000	1.000	0.988	1.000	1.000	1.000
	1.74	4	0.996	1.000	1.004	1.000	1.007	1.000
	1.53	4	1.000	1.000	1.008	1.000	1.000	1.000
	1.00	3	1.000	1.000	0.990	1.000	0.990	1.000
flugpl	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
gt2	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
harp2	691.56	1491878	1.008	1.000	0.999	1.000	1.005	1.000
	1159.66	2857677	0.998	1.000	0.998	1.000	0.997	1.000
	336.73	595854	0.999	1.000	1.006	1.000	0.999	1.000
	937.54	2046181	0.999	1.000	1.002	1.000	1.002	1.000
	425.68	923780	1.013	1.000	1.007	1.000	1.008	1.000
iis-100-0-cov	629.92	103302	0.998	1.000	1.021	1.000	0.992	1.000
	545.20	92393	0.995	1.000	0.997	1.000	1.001	1.000
	520.78	81639	1.001	1.000	1.000	1.000	1.000	1.000
	506.53	84800	0.999	1.000	0.995	1.000	1.000	1.000
	544.56	92313	1.007	1.000	1.003	1.000	1.004	1.000
iis-bupa-cov	1915.72	157619	1.000	1.000	1.003	1.000	1.001	1.000
	1944.83	164079	0.999	1.000	0.996	1.000	0.999	1.000
	1881.83	156888	0.991	1.000	0.992	1.000	1.008	1.000
	1959.19	161969	0.994	1.000	0.999	1.000	0.997	1.000
	1820.52	158284	0.994	1.000	0.993	1.000	1.014	1.000
iis-pima-cov	293.79	4824	1.004	1.000	0.999	1.000	0.999	1.000
	437.19	12189	1.007	1.000	1.001	1.000	1.013	1.000
	246.99	4668	1.002	1.000	1.000	1.000	1.002	1.000
	284.88	6607	1.002	1.000	1.000	1.000	1.003	1.000
	556.78	17821	0.997	1.000	0.997	1.000	1.001	1.000
l152lav	5.51	23	1.011	1.000	1.014	1.000	0.992	1.000
	1.67	31	0.989	1.000	0.993	1.000	1.000	1.000

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Table C.3: Computational results on MMM-IP: Impact of combined criteria.

	default		degeneracy + leaves		leaves + obj		all6criterion	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	2.93	50	0.995	1.000	1.003	1.000	1.000	1.000
	2.34	20	0.985	1.000	0.994	1.000	0.991	1.000
	3.02	52	1.000	1.000	1.012	1.000	1.002	1.000
lectsched-4-obj	27.04	805	**0.750**	**0.215**	*1.052*	**0.838**	**0.749**	**0.215**
	23.16	796	*1.193*	**0.288**	1.008	**0.823**	*1.198*	**0.288**
	86.08	2419	**0.285**	**0.206**	**0.626**	**0.461**	**0.265**	**0.121**
	26.83	1231	**0.327**	**0.082**	**0.933**	**0.540**	**0.331**	**0.082**
	22.73	745	**0.903**	**0.253**	0.992	0.954	**0.911**	**0.253**
lseu	0.75	268	0.994	1.000	1.029	1.000	1.006	1.000
	0.50	4	1.000	1.000	1.000	1.000	1.000	1.000
	0.51	205	0.993	1.000	0.993	1.000	1.000	1.000
	0.50	91	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	191	1.000	1.000	1.000	1.000	1.000	1.000
m100n500k4r1	3600.00	2170459	1.000	*1.118*	1.000	1.002	1.000	**0.781**
	3600.00	2278212	1.000	1.035	1.000	0.996	1.000	**0.783**
	3600.00	2617105	1.000	**0.884**	1.000	1.000	1.000	**0.560**
	3600.00	2309660	1.000	**0.935**	1.000	0.998	1.000	**0.638**
	3600.00	2245563	1.000	**0.834**	1.000	0.996	1.000	**0.647**
macrophage	125.50	5163	1.000	1.000	1.006	1.000	1.001	1.000
	157.18	7241	0.998	1.000	0.998	1.000	0.999	1.000
	209.11	9131	1.000	1.000	1.000	1.000	1.001	1.000
	162.53	7927	0.998	1.000	1.000	1.000	1.002	1.000
	121.37	5239	0.995	1.000	0.996	1.000	0.997	1.000
manna81	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
markshare1	3600.00	19093205	1.000	**0.927**	1.000	0.997	1.000	**0.924**
	3600.00	20203360	1.000	**0.859**	1.000	0.998	1.000	**0.856**
	3600.00	19520584	1.000	**0.919**	1.000	0.999	1.000	**0.918**
	3600.00	20427204	1.000	**0.901**	1.000	1.000	1.000	**0.903**
	3600.00	21513467	1.000	**0.795**	1.000	1.000	1.000	**0.796**
markshare2	3600.00	4072360	1.000	**0.843**	1.000	0.995	1.000	**0.847**
	3600.00	5640455	1.000	**0.699**	1.000	1.000	1.000	**0.699**
	3600.00	3582521	1.000	1.025	1.000	0.998	1.000	1.023
	3600.00	4239467	1.000	*1.067*	1.000	1.006	1.000	*1.070*
	3600.00	5142521	1.000	**0.828**	1.000	1.004	1.000	**0.836**
mcsched	285.92	13689	0.999	1.000	1.000	1.000	0.997	1.000
	271.88	11373	0.999	1.000	0.999	1.000	1.001	1.000
	233.97	10059	1.003	1.000	0.995	1.000	1.000	1.000
	286.25	12496	0.995	1.000	1.000	1.000	0.997	1.000
	270.69	10373	1.004	1.000	0.999	1.000	1.000	1.000
mine-166-5	58.69	1569	0.995	1.000	1.001	1.000	0.998	1.000
	57.78	1191	0.993	1.000	0.994	1.000	0.992	1.000
	46.45	2244	0.997	1.000	1.004	1.000	1.005	1.000
	64.93	139	0.998	1.000	1.007	1.000	1.000	1.000
	42.28	2863	1.001	1.000	1.001	1.000	1.000	1.000
mine-90-10	276.07	47643	*1.162*	*1.090*	*1.162*	*1.090*	*1.157*	*1.090*
	125.32	22195	0.999	1.000	0.997	1.000	1.002	1.000
	173.25	25979	1.001	1.000	0.999	1.000	1.000	1.000
	500.83	87496	*1.322*	*1.061*	*1.321*	*1.061*	*1.322*	*1.061*
	236.18	32520	**0.907**	*1.242*	**0.908**	*1.242*	**0.904**	*1.242*
misc03	1.39	398	1.008	1.000	0.996	1.000	0.992	1.000
	0.71	15	0.994	1.000	1.018	1.000	*1.094*	*1.226*
	0.70	19	1.006	1.000	1.006	1.000	*1.200*	*1.370*
	1.00	111	1.000	1.000	0.990	1.000	0.995	1.000
	0.66	15	1.018	1.000	0.994	1.000	*1.193*	*1.609*
misc07	38.05	28289	0.998	1.000	1.026	1.000	*1.090*	*1.188*
	36.66	29782	0.999	1.000	0.999	1.000	0.999	1.000
	21.56	17632	0.999	1.000	0.996	1.000	0.994	1.000
	45.95	38975	1.006	1.000	1.007	1.000	1.004	1.000

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Table C.3: Computational results on MMM-IP: Impact of combined criteria.

	default		degeneracy + leaves		leaves + obj		all6criterion	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	30.94	29476	0.993	1.000	0.996	1.000	*1.088*	**0.937**
mitre	10.20	1	*1.376*	1.000	0.992	1.000	*1.354*	1.000
	10.28	1	*1.444*	1.000	1.009	1.000	*1.473*	1.000
	10.94	1	*1.380*	1.000	0.960	1.000	*1.391*	1.000
	10.45	1	*1.401*	1.000	0.994	1.000	*1.399*	1.000
	13.12	1	1.038	1.000	0.991	1.000	*1.051*	1.000
mod008	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.54	2	1.000	1.000	1.000	1.000	1.000	1.000
	0.52	2	1.000	1.000	0.993	1.000	1.000	1.000
	0.52	1	0.993	1.000	0.993	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
mod010	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.52	2	1.000	1.000	0.993	1.000	0.993	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
mzzv11	332.43	2022	0.999	1.000	0.994	1.000	1.000	1.000
	229.41	959	1.002	1.000	1.003	1.000	1.001	1.000
	310.05	1421	0.998	1.000	1.000	1.000	0.998	1.000
	327.03	1579	0.994	1.000	0.995	1.000	0.994	1.000
	186.14	627	1.001	1.000	1.002	1.000	1.000	1.000
mzzv42z	152.40	265	0.994	1.000	0.992	1.000	0.993	1.000
	131.25	125	0.993	1.000	0.993	1.000	*1.105*	*1.053*
	197.62	200	1.004	1.000	1.006	1.000	1.024	**0.923**
	213.83	456	0.999	1.000	1.001	1.000	**0.933**	**0.736**
	167.65	300	1.000	1.000	1.000	1.000	1.004	1.000
neos-1109824	37.52	1796	0.998	1.000	0.995	1.000	*1.662*	*2.859*
	46.67	3438	1.000	1.000	0.998	1.000	1.009	0.969
	35.16	1913	0.999	1.000	0.998	1.000	*1.088*	0.966
	77.65	8290	1.003	1.000	1.003	1.000	**0.696**	**0.534**
	39.64	2247	0.993	1.000	0.991	1.000	*1.156*	*1.084*
neos-1337307	3600.00	302483	1.000	1.004	1.000	1.006	1.000	*1.178*
	3600.00	269510	1.000	1.001	1.000	1.003	1.000	*1.084*
	3600.00	348643	1.000	1.002	1.000	1.000	1.000	1.012
	3600.00	300587	1.000	1.011	1.000	0.993	1.000	*1.131*
	3600.00	367746	1.000	1.002	1.000	1.007	1.000	**0.748**
neos-1601936	2034.60	1453	0.996	1.000	1.009	1.000	*1.769*	*2.100*
	3600.00	2849	1.000	1.003	1.000	1.000	1.000	**0.377**
	1348.55	2661	1.000	1.000	1.000	1.000	*2.668*	**0.581**
	3600.00	6919	1.000	0.999	1.000	0.999	1.000	**0.584**
	3600.00	6139	1.000	1.000	1.000	1.010	0.993	**0.519**
neos-686190	83.42	4906	1.003	1.000	0.997	1.000	0.995	1.000
	86.19	6047	1.001	1.000	1.000	1.000	1.002	1.000
	114.74	9156	1.000	1.000	1.001	1.000	1.000	1.000
	116.53	9998	1.008	1.000	1.002	1.000	0.999	1.000
	121.04	9806	1.004	1.000	1.003	1.000	0.998	1.000
neos-849702	114.99	2031	*1.820*	**0.595**	*1.817*	**0.595**	*1.804*	**0.595**
	353.12	17540	*2.901*	**0.364**	*2.924*	**0.364**	*2.903*	**0.364**
	357.57	29405	*2.792*	**0.359**	*2.795*	**0.359**	*2.803*	**0.359**
	261.49	16226	1.025	**0.048**	1.027	**0.048**	1.025	**0.048**
	143.57	4968	*1.988*	**0.335**	*1.991*	**0.335**	*1.994*	**0.335**
neos-934278	3600.00	1184	1.000	0.991	1.000	0.993	1.000	0.993
	3600.00	265	1.000	1.014	1.000	1.011	1.000	1.003
	3600.00	263	1.000	1.000	1.000	1.000	1.000	0.989
	3600.00	391	1.000	1.014	1.000	1.014	1.000	0.963
	3600.00	521	1.000	1.002	1.000	0.997	1.000	0.998
neos18	24.17	1378	**0.360**	**0.121**	1.004	1.047	**0.359**	**0.121**
	21.26	1321	*1.154*	**0.653**	1.027	*1.199*	0.971	**0.467**
	23.36	1646	*1.227*	**0.684**	1.000	1.000	*1.229*	**0.684**
	19.21	996	**0.808**	**0.443**	1.003	1.000	**0.805**	**0.443**
	22.07	1049	0.989	**0.925**	0.997	1.000	0.951	**0.795**
ns1208400	2439.01	14168	**0.485**	**0.271**	**0.146**	**0.062**	**0.484**	**0.271**

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Table C.3: Computational results on MMM-IP: Impact of combined criteria.

	default		degeneracy + leaves		leaves + obj		all6criterion	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	1985.63	7882	*1.390*	*1.450*	*1.673*	**0.733**	*1.392*	*1.450*
	1467.85	5026	**0.367**	**0.355**	**0.416**	**0.283**	**0.367**	**0.355**
	3600.00	5611	**0.071**	**0.122**	**0.274**	**0.476**	**0.071**	**0.122**
	2388.79	8711	**0.050**	**0.068**	**0.650**	**0.464**	**0.051**	**0.068**
ns1688347	55.09	451	**0.942**	0.975	*1.215*	*1.666*	**0.940**	0.975
	45.64	485	**0.930**	**0.518**	*1.058*	**0.892**	**0.929**	**0.518**
	106.90	1865	*1.530*	*1.438*	*1.160*	**0.638**	*1.330*	*1.366*
	139.57	1219	0.956	1.024	**0.942**	*1.088*	*1.205*	*1.089*
	55.82	745	**0.858**	**0.527**	**0.724**	**0.608**	**0.862**	**0.527**
ns1830653	132.81	6918	**0.813**	**0.829**	**0.811**	**0.829**	0.980	**0.788**
	123.49	5226	*1.250*	*1.054*	*1.251*	*1.054*	*1.515*	*1.580*
	161.13	9597	**0.948**	*1.090*	**0.946**	*1.090*	**0.863**	**0.656**
	143.05	7435	*1.065*	1.011	*1.069*	1.011	**0.901**	**0.816**
	146.20	9194	**0.783**	**0.639**	**0.782**	**0.639**	*1.160*	**0.740**
nsrand-ipx	422.05	50124	0.998	1.000	1.003	1.000	*1.297*	**0.946**
	643.65	86869	0.999	1.000	0.999	1.000	*1.274*	**0.923**
	568.28	56575	1.004	1.000	1.006	1.000	*1.058*	0.996
	582.50	61056	0.996	1.000	1.006	1.000	*2.291*	**0.885**
	367.03	38012	0.995	1.000	0.994	1.000	*1.147*	1.032
opt1217	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
p0033	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
p0201	0.55	5	0.981	1.000	0.987	1.000	0.987	1.000
	0.71	9	1.018	1.000	1.023	1.000	0.994	1.000
	1.59	5	1.015	1.000	1.015	1.000	1.004	1.000
	0.90	13	1.005	1.000	1.000	1.000	1.005	1.000
	0.91	59	0.984	1.000	0.984	1.000	0.984	1.000
p0282	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	3	1.007	1.000	1.000	1.000	1.007	1.000
	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000
p0548	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000
p2756	2.46	5	1.006	1.000	1.012	1.000	1.000	1.000
	3.33	5	1.005	1.000	1.018	1.000	0.995	1.000
	2.16	3	0.994	1.000	0.987	1.000	0.994	1.000
	2.60	3	0.994	1.000	0.992	1.000	0.975	1.000
	1.22	2	1.036	1.000	1.027	1.000	1.041	1.000
protfold	3600.00	4783	1.000	**0.685**	1.000	1.008	1.000	**0.685**
	3600.00	8172	1.000	**0.314**	1.000	1.003	1.000	**0.315**
	3600.00	5838	1.000	**0.478**	1.000	1.004	1.000	**0.480**
	3600.00	7263	1.000	**0.262**	1.000	1.000	1.000	**0.263**
	3600.00	5620	1.000	**0.348**	1.000	**0.844**	1.000	**0.345**
pw-myciel4	3600.00	519843	1.000	**0.696**	**0.656**	**0.587**	1.000	**0.901**
	3600.00	443116	1.000	**0.824**	**0.930**	0.954	1.000	**0.688**
	3600.00	391642	1.000	**0.830**	1.000	0.968	1.000	0.969
	2920.77	395762	*1.232*	**0.907**	*1.232*	**0.872**	*1.232*	*1.067*
	3600.00	405235	**0.847**	**0.934**	**0.938**	1.044	1.000	**0.856**
qnet1	4.52	33	1.004	1.000	1.009	1.000	1.007	1.000
	3.09	3	1.000	1.000	1.002	1.000	1.000	1.000
	3.94	29	1.002	1.000	1.004	1.000	1.000	1.000

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Table C.3: Computational results on MMM-IP: Impact of combined criteria.

	default		degeneracy + leaves		leaves + obj		all6criterion	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	2.23	3	0.994	1.000	0.994	1.000	1.006	1.000
	3.69	34	0.998	1.000	0.998	1.000	0.989	1.000
qnet1_o	3.93	27	1.008	1.000	0.986	1.000	1.004	1.000
	3.35	24	1.009	1.000	1.005	1.000	1.002	1.000
	3.37	15	1.000	1.000	1.007	1.000	1.000	1.000
	1.66	2	1.008	1.000	1.004	1.000	0.992	1.000
	1.83	3	1.004	1.000	1.000	1.000	1.004	1.000
reblock67	222.59	49530	0.997	1.000	0.997	1.000	1.001	1.000
	161.89	40625	0.993	1.000	1.002	1.000	1.000	1.000
	194.41	49882	**0.858**	**0.853**	**0.866**	**0.853**	**0.859**	**0.853**
	199.06	50996	0.991	1.032	0.994	1.032	0.998	1.032
	239.84	57566	0.993	1.000	0.996	1.000	0.997	1.000
rmine6	971.86	111047	1.004	1.000	1.000	1.000	0.999	1.000
	883.48	89213	1.001	1.000	0.990	1.000	1.001	1.000
	775.32	91530	1.005	1.000	0.999	1.000	1.011	1.000
	740.58	85429	1.003	1.000	0.993	1.000	1.006	1.000
	771.48	76017	0.999	1.000	1.000	1.000	1.004	1.000
rococoC10-001000	601.83	46983	0.999	1.000	0.999	1.000	0.997	1.000
	833.40	75156	1.008	1.000	1.004	1.000	0.996	1.000
	517.62	37178	1.003	1.000	*1.090*	*1.105*	*1.089*	*1.105*
	892.04	51410	1.002	1.000	1.002	1.000	1.002	1.000
	1047.39	66016	1.000	1.000	1.001	1.000	1.001	1.000
seymour	3600.00	102645	1.000	0.996	1.000	0.999	1.000	0.997
	3600.00	120322	1.000	0.999	1.000	0.997	1.000	0.998
	3600.00	122337	1.000	1.006	1.000	1.004	1.000	1.007
	3600.00	107537	1.000	0.998	1.000	1.000	1.000	0.996
	3600.00	96726	1.000	1.007	1.000	1.001	1.000	0.999
sp98ir	57.90	3948	1.004	1.000	1.006	1.000	1.001	1.000
	65.87	4178	1.002	1.000	1.004	1.000	0.996	1.000
	67.64	4735	1.005	1.000	1.003	1.000	1.001	1.000
	72.68	4603	0.995	1.000	0.995	1.000	1.002	1.000
	70.05	4780	1.004	1.000	1.000	1.000	1.000	1.000
stein27	1.12	2749	1.009	1.000	1.024	1.000	1.024	1.000
	1.19	2699	1.009	1.000	0.991	1.000	1.000	1.000
	1.25	2889	0.991	1.000	0.982	1.000	0.996	1.000
	1.14	2715	0.977	*1.056*	0.963	1.000	0.991	*1.056*
	1.13	2911	0.981	0.972	0.991	1.000	1.023	0.972
stein45	12.80	40723	0.967	0.962	0.987	1.000	1.041	1.002
	12.94	39012	0.963	0.995	0.999	1.000	0.991	0.995
	13.04	41930	1.010	0.985	0.998	1.000	1.015	0.985
	12.20	37543	1.038	1.015	0.998	1.000	1.044	1.015
	13.29	40503	0.984	1.006	0.985	1.000	1.003	1.006
tanglegram2	4.09	3	1.012	1.000	1.006	1.000	1.010	1.000
	3.85	3	1.000	1.000	1.006	1.000	0.996	1.000
	4.25	3	0.998	1.000	0.996	1.000	1.050	1.000
	4.11	3	0.994	1.000	0.990	1.000	1.004	1.000
	4.23	3	0.990	1.000	0.992	1.000	0.998	1.000

Table C.4: Computational results on MMM-IP: Impact of transferred information. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	degeneracy		variablebounds		conflicts		infervals		primsols	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
10teams	3.01	1	0.990	1.000	**0.825**	1.000	0.995	1.000	0.988	1.000
	4.07	5	1.006	1.000	*1.266*	1.000	*1.162*	1.000	1.026	1.000
	25.62	956	1.012	1.000	**0.668**	**0.159**	*1.091*	*1.195*	**0.441**	**0.118**
	13.04	28	0.998	1.000	**0.331**	**0.820**	**0.428**	**0.820**	1.002	1.000
	4.40	5	1.004	1.000	*4.026*	*2.943*	*1.278*	1.000	1.007	1.000
30n20b8	189.53	63	*1.521*	*1.245*	*1.573*	*1.607*	*1.458*	*1.503*	1.000	1.000
	111.78	2	*2.089*	*1.873*	*1.975*	*1.676*	1.023	1.000	0.998	1.000
	87.35	4	1.001	1.000	0.993	1.000	0.999	1.000	1.001	1.000
	257.61	165	**0.841**	**0.762**	0.994	1.000	1.009	1.000	1.004	1.000
	381.26	182	0.982	**0.926**	*1.061*	**0.858**	1.005	1.000	0.999	1.000
acc-tight5	139.72	956	*1.284*	*1.562*	**0.205**	**0.116**	**0.433**	**0.267**	*1.560*	*1.788*
	110.82	1160	**0.516**	**0.318**	*1.515*	*1.136*	**0.513**	**0.239**	*1.140*	*1.150*
	49.06	174	*2.796*	*4.310*	*1.596*	*2.558*	**0.623**	**0.442**	*1.712*	*2.423*
	28.52	22	*2.037*	*1.828*	*2.899*	*4.975*	*1.400*	*1.434*	*5.993*	*11.180*
	30.00	17	1.019	1.000	**0.936**	*1.325*	*2.597*	*3.556*	1.012	*1.103*
air03	1.73	1	1.000	1.000	1.007	1.000	0.993	1.000	1.011	1.000
	1.72	1	1.015	1.000	1.000	1.000	1.011	1.000	0.996	1.000
	1.72	1	1.011	1.000	1.007	1.000	1.000	1.000	1.007	1.000
	1.75	1	1.000	1.000	0.993	1.000	0.993	1.000	1.004	1.000
	1.74	1	1.026	1.000	1.007	1.000	0.989	1.000	1.000	1.000
air04	49.60	110	1.009	1.000	1.008	1.000	1.008	1.000	1.008	1.000
	36.38	39	1.001	1.000	0.995	1.000	0.997	1.000	0.995	1.000
	53.17	118	0.999	1.000	0.988	1.000	0.998	1.000	1.002	1.000
	37.09	31	0.995	1.000	0.993	1.000	0.992	1.000	0.996	1.000
	48.66	122	0.996	1.000	0.994	1.000	1.002	1.000	0.999	1.000
air05	24.56	189	1.002	1.000	1.002	1.000	1.001	1.000	1.002	1.000
	26.64	239	1.000	1.000	0.998	1.000	0.998	1.000	1.009	1.000
	31.10	438	1.002	1.000	1.005	1.000	1.046	1.000	1.003	1.000
	27.57	283	1.000	1.000	1.000	1.000	0.999	1.000	0.998	1.000
	27.23	279	1.000	1.000	0.996	1.000	0.998	1.000	0.993	1.000
blend2	0.76	714	0.989	1.000	0.994	1.000	0.972	1.000	1.006	1.000
	1.05	973	1.015	1.000	0.980	1.000	1.005	1.000	1.005	1.000
	1.06	912	0.985	1.000	0.985	1.000	0.990	1.000	1.005	1.000
	0.66	543	1.018	1.000	0.994	1.000	0.994	1.000	1.012	1.000
	0.71	709	0.994	1.000	0.988	1.000	1.000	1.000	1.000	1.000
bley_xl1	163.94	1	0.996	1.000	1.004	1.000	1.005	1.000	1.004	1.000
	189.31	18	0.999	1.000	1.002	1.000	*1.052*	*1.314*	*1.107*	*1.458*
	162.64	2	0.984	1.000	0.999	1.000	1.000	1.000	1.003	1.000
	134.67	1	0.997	1.000	1.001	1.000	0.998	1.000	0.999	1.000
	136.43	1	1.003	1.000	1.001	1.000	1.003	1.000	1.003	1.000
bnatt350	18.90	6	**0.897**	1.000	*6.188*	*7.047*	*2.522*	*1.330*	*19.530*	*40.189*
	16.29	10	*1.098*	1.000	*27.910*	*46.845*	*2.398*	*1.309*	*13.634*	*15.082*
	18.02	6	**0.834**	1.000	*15.298*	*20.085*	*3.298*	*3.075*	*13.075*	*20.151*
	16.08	7	0.999	1.000	*12.361*	*12.720*	*1.444*	1.047	*17.894*	*26.383*
	43.21	112	**0.732**	**0.623**	*9.481*	*21.113*	*2.919*	*3.425*	*10.242*	*27.854*
cap6000	2.70	1830	1.008	1.000	1.000	1.000	1.003	1.000	1.005	1.000
	2.62	1837	0.992	1.000	1.017	1.000	0.978	1.000	1.003	1.000
	2.58	1959	1.025	1.000	1.028	1.000	1.011	1.000	1.014	1.000
	3.20	1924	0.976	1.000	0.983	1.000	0.974	1.000	0.993	1.000
	2.85	1762	0.982	1.000	0.992	1.000	0.992	1.000	0.984	1.000
cov1075	3560.96	1725170	1.001	1.000	1.001	1.000	1.011	**0.827**	1.001	1.000
	3600.00	1745291	1.000	1.000	1.000	1.006	1.000	1.009	1.000	1.003
	3600.00	1834965	1.000	0.998	1.000	1.001	1.000	**0.823**	1.000	0.990
	3600.00	1771419	1.000	1.000	1.000	0.999	1.000	1.007	1.000	1.000
	3600.00	1817274	1.000	0.999	1.000	0.999	1.000	**0.657**	1.000	0.999
csched010	3600.00	237694	1.000	0.997	1.000	0.997	1.000	0.996	1.000	0.997
	3600.00	203138	1.000	1.000	1.000	1.002	1.000	0.999	1.000	1.000
	2893.02	177527	0.998	1.000	1.001	1.000	1.000	1.000	0.999	1.000
	3600.00	238053	1.000	1.003	1.000	1.001	1.000	0.999	1.000	0.998
	3171.41	173932	0.999	1.000	0.999	1.000	0.998	1.000	1.000	1.000

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Table C.4: Computational results on MMM-IP: Impact of transferred information.

Instance	degeneracy		variablebounds		conflicts		infervals		primsols	
	T	**N**	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
eil33-2	69.62	583	1.004	1.000	1.001	1.000	0.996	1.000	1.003	1.000
	82.52	739	0.994	1.000	0.994	1.000	0.999	1.000	0.981	1.000
	83.95	847	1.012	1.000	1.013	1.000	1.016	1.000	1.010	1.000
	72.71	543	1.015	1.000	1.019	1.000	1.016	1.000	1.005	1.000
	69.08	583	1.016	1.000	1.016	1.000	1.015	1.000	1.017	1.000
eilB101	378.34	10582	0.995	1.000	0.990	1.000	1.012	1.000	1.000	1.000
	359.35	8427	1.009	1.000	1.001	1.000	1.017	1.000	1.011	1.000
	399.77	9358	1.003	1.000	0.999	1.000	0.999	1.000	1.005	1.000
	396.04	11465	1.006	1.000	0.995	1.000	1.012	1.000	0.997	1.000
	361.93	10006	1.009	1.000	1.011	1.000	1.013	1.000	1.006	1.000
enigma	0.50	650	1.000	0.997	1.033	*768.000*	*1.113*	*1.135*	1.000	1.033
	0.50	173	1.000	*1.681*	1.000	*1.905*	1.000	*1.495*	1.000	1.000
	0.50	63	1.000	*1.374*	1.000	*1.123*	1.027	*4.491*	1.000	1.000
	0.61	318	**0.932**	**0.289**	**0.932**	*1.122*	1.031	*1.218*	0.975	1.000
	0.53	196	1.013	*1.588*	0.980	**0.405**	0.980	*1.493*	1.000	1.000
enlight13	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
enlight14	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
fiber	1.02	2	0.995	1.000	0.980	1.000	1.000	1.000	1.000	1.000
	1.39	4	1.004	1.000	1.008	1.000	1.013	1.000	1.004	1.000
	1.76	4	0.982	1.000	0.996	1.000	0.978	1.000	0.993	1.000
	1.55	4	1.000	1.000	0.988	1.000	0.988	1.000	0.988	1.000
	1.00	3	0.995	1.000	1.010	1.000	1.005	1.000	1.005	1.000
flugpl	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
gt2	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
harp2	694.94	1491878	1.003	1.000	0.999	1.000	0.996	1.000	0.989	1.000
	1163.82	2857677	0.992	1.000	0.989	1.000	0.993	1.000	0.993	1.000
	333.99	595854	1.008	1.000	1.002	1.000	1.011	1.000	1.009	1.000
	934.82	2046181	1.006	1.000	0.999	1.000	1.001	1.000	1.003	1.000
	433.24	923780	0.998	1.000	0.985	1.000	0.991	1.000	0.996	1.000
iis-100-0-cov	625.29	103302	0.999	1.000	1.002	1.000	0.998	1.000	0.998	1.000
	544.56	92393	1.001	1.000	1.025	1.000	0.999	1.000	1.001	1.000
	520.20	81639	1.022	1.000	1.018	1.000	*1.069*	1.000	1.007	1.000
	507.53	84800	0.995	1.000	1.008	1.000	1.001	1.000	1.025	1.000
	542.59	92313	*1.055*	1.000	1.036	1.000	1.011	1.000	1.016	1.000
iis-bupa-cov	1917.51	157619	0.991	1.000	0.994	1.000	0.997	1.000	0.996	1.000
	1939.94	164079	1.010	1.000	1.019	1.000	1.014	1.000	1.020	1.000
	1878.21	156888	*1.053*	1.000	0.998	1.000	1.024	1.000	1.003	1.000
	1938.34	161969	1.002	1.000	1.022	1.000	1.026	1.000	1.002	1.000
	1802.15	158284	1.030	1.000	1.048	1.000	1.003	1.000	1.030	1.000
iis-pima-cov	292.21	4824	1.006	1.000	1.002	1.000	1.002	1.000	1.006	1.000
	434.93	12189	1.020	1.000	1.000	1.000	1.025	1.000	1.039	1.000
	246.99	4668	1.007	1.000	1.019	1.000	1.009	1.000	0.995	1.000
	285.55	6607	1.005	1.000	1.006	1.000	1.011	1.000	1.015	1.000
	558.43	17821	1.017	1.000	0.998	1.000	1.002	1.000	1.048	1.000
l152lav	5.47	23	0.994	1.000	0.998	1.000	1.009	1.000	1.000	1.000
	1.63	31	1.011	1.000	1.015	1.000	0.996	1.000	1.011	1.000

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Table C.4: Computational results on `MMM-IP`: Impact of transferred information.

	degeneracy		variablebounds		conflicts		infervals		primsols	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	2.93	50	0.992	1.000	0.987	1.000	1.000	1.000	1.003	1.000
	2.29	20	1.006	1.000	1.012	1.000	1.009	1.000	1.009	1.000
	3.00	52	1.012	1.000	1.010	1.000	1.015	1.000	1.012	1.000
lectsched-4-obj	20.11	95	0.957	*1.113*	*1.624*	*3.487*	1.008	*1.913*	*2.428*	*4.513*
	28.02	158	*1.120*	*1.093*	*1.242*	*2.430*	0.989	**0.930**	*2.457*	*2.988*
	24.11	565	**0.645**	**0.415**	*1.559*	*1.989*	*1.552*	*1.788*	*2.656*	*1.714*
	8.09	9	1.022	1.000	**0.865**	1.000	**0.818**	0.963	*9.364*	*11.716*
	20.57	114	*1.340*	*1.178*	*1.510*	*3.664*	*1.381*	*2.271*	*7.981*	*9.061*
lseu	0.77	268	1.011	1.000	0.977	1.000	1.000	1.000	0.994	1.000
	0.50	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	205	1.000	1.000	1.020	1.000	1.000	1.000	1.000	1.000
	0.50	91	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.51	191	0.993	1.000	1.007	1.000	0.993	1.000	1.020	1.000
m100n500k4r1	3600.00	2426435	1.000	1.032	1.000	0.997	1.000	0.957	1.000	**0.883**
	3600.00	2358830	1.000	0.997	1.000	0.993	1.000	*1.414*	1.000	**0.897**
	3600.00	2313256	1.000	1.028	1.000	0.982	1.000	1.039	1.000	0.982
	3600.00	2163125	1.000	1.040	1.000	0.997	1.000	*1.441*	1.000	**0.950**
	3600.00	1871050	1.000	*1.054*	1.000	0.975	1.000	*1.115*	1.000	1.032
macrophage	125.68	5163	1.001	1.000	0.999	1.000	1.002	1.000	1.001	1.000
	157.07	7241	1.007	1.000	1.007	1.000	1.007	1.000	1.005	1.000
	209.04	9131	1.010	1.000	0.998	1.000	1.003	1.000	1.006	1.000
	162.46	7927	1.039	1.000	1.002	1.000	1.013	1.000	1.008	1.000
	121.23	5239	0.997	1.000	1.015	1.000	0.998	1.000	1.014	1.000
manna81	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
markshare1	3600.00	17773362	1.000	*1.150*	1.000	0.990	1.000	1.038	1.000	**0.655**
	3600.00	17405834	1.000	*1.184*	1.000	0.998	1.000	*1.126*	1.000	1.000
	3600.00	17945211	1.000	*1.149*	1.000	1.001	1.000	0.954	1.000	**0.482**
	3600.00	18348094	1.000	*1.131*	1.000	1.003	1.000	0.980	1.000	**0.853**
	3600.00	17151823	1.000	*1.130*	1.000	0.997	1.000	*1.050*	1.000	**0.889**
markshare2	3600.00	3433363	1.000	*1.178*	1.000	1.003	1.000	*1.352*	1.000	*1.064*
	3600.00	3929356	1.000	**0.901**	1.000	1.003	1.000	*1.127*	1.000	**0.877**
	3600.00	3675025	1.000	1.036	1.000	1.000	1.000	0.975	1.000	1.004
	3600.00	4532415	1.000	**0.819**	1.000	0.999	1.000	1.032	1.000	**0.789**
	3600.00	4267105	1.000	**0.860**	1.000	1.009	1.000	**0.887**	1.000	*1.101*
mcsched	285.70	13689	1.000	1.000	0.998	1.000	1.004	1.000	1.000	1.000
	271.59	11373	0.998	1.000	1.015	1.000	1.022	1.000	0.999	1.000
	233.00	10059	1.014	1.000	1.036	1.000	1.006	1.000	1.001	1.000
	285.38	12496	1.011	1.000	1.003	1.000	0.998	1.000	0.996	1.000
	272.13	10373	0.997	1.000	1.009	1.000	1.027	1.000	1.016	1.000
mine-166-5	58.40	1569	0.997	1.000	0.998	1.000	0.997	1.000	0.999	1.000
	57.21	1191	1.007	1.000	1.003	1.000	0.998	1.000	1.005	1.000
	46.49	2244	*1.064*	1.000	1.010	1.000	1.007	1.000	0.999	1.000
	65.30	139	0.991	1.000	1.003	1.000	1.043	1.000	1.003	1.000
	42.28	2863	*1.061*	1.000	1.002	1.000	1.021	1.000	1.019	1.000
mine-90-10	276.51	47643	1.001	1.000	0.997	1.000	0.999	1.000	0.997	1.000
	125.11	22195	1.002	1.000	1.001	1.000	1.013	1.000	1.018	1.000
	173.38	25979	1.042	1.000	1.001	1.000	1.010	1.000	1.020	1.000
	502.57	87496	0.998	1.000	0.995	1.000	1.005	1.000	0.997	1.000
	237.48	32520	1.002	1.000	*1.054*	1.000	0.992	1.000	0.999	1.000
misc03	1.40	398	0.988	1.000	0.992	1.000	0.983	1.000	0.988	1.000
	0.71	15	1.023	1.000	1.018	1.000	1.006	1.000	1.000	1.000
	0.73	19	1.000	1.000	0.983	1.000	0.988	1.000	0.977	1.000
	0.98	111	1.025	1.000	1.015	1.000	0.990	1.000	1.020	1.000
	0.64	15	1.018	1.000	1.000	1.000	1.000	1.000	1.018	1.000
misc07	38.28	28289	0.997	1.000	0.990	1.000	0.982	1.000	0.995	1.000
	36.49	29782	1.007	1.000	1.006	1.000	1.006	1.000	1.007	1.000
	21.45	17632	1.003	1.000	1.010	1.000	1.004	1.000	1.003	1.000
	45.80	38975	1.014	1.000	1.013	1.000	1.004	1.000	1.007	1.000

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Table C.4: Computational results on MMM-IP: Impact of transferred information.

	degeneracy		variablebounds		conflicts		infervals		primsols	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	30.56	29476	1.010	1.000	1.014	1.000	1.009	1.000	1.009	1.000
mitre	14.57	1	1.006	1.000	**0.757**	1.000	0.984	1.000	0.988	1.000
	15.57	1	0.992	1.000	**0.717**	1.000	0.993	1.000	0.999	1.000
	15.52	1	1.005	1.000	**0.718**	1.000	1.005	1.000	1.001	1.000
	15.17	1	0.988	1.000	**0.746**	1.000	0.994	1.000	1.001	1.000
	13.39	1	1.037	1.000	0.994	1.000	1.027	1.000	1.028	1.000
mod008	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.53	2	1.000	1.000	0.987	1.000	1.013	1.000	1.007	1.000
	0.54	2	0.987	1.000	0.981	1.000	0.987	1.000	0.994	1.000
	0.51	1	1.000	1.000	1.000	1.000	1.007	1.000	1.013	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
mod010	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.53	2	0.993	1.000	0.980	1.000	1.000	1.000	0.987	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
mzzv11	332.03	2022	0.995	1.000	0.995	1.000	0.998	1.000	0.996	1.000
	229.82	959	1.005	1.000	0.999	1.000	0.991	1.000	0.999	1.000
	311.22	1421	0.987	1.000	1.000	1.000	0.996	1.000	0.988	1.000
	322.67	1579	1.009	1.000	1.014	1.000	1.009	1.000	0.998	1.000
	186.23	627	1.002	1.000	0.999	1.000	1.000	1.000	0.997	1.000
mzzv42z	151.11	265	0.994	1.000	1.003	1.000	1.001	1.000	1.001	1.000
	131.14	125	0.994	1.000	0.995	1.000	0.998	1.000	0.995	1.000
	198.89	200	1.000	1.000	0.996	1.000	0.995	1.000	0.999	1.000
	214.35	456	0.997	1.000	1.005	1.000	0.998	1.000	0.990	1.000
	167.53	300	1.005	1.000	0.998	1.000	1.000	1.000	1.001	1.000
neos-1109824	37.38	1796	0.998	1.000	0.997	1.000	0.996	1.000	0.997	1.000
	46.57	3438	1.012	1.000	1.006	1.000	1.008	1.000	1.035	1.000
	34.97	1913	1.013	1.000	1.009	1.000	1.021	1.000	1.022	1.000
	77.32	8290	1.043	1.000	1.005	1.000	*1.055*	1.000	1.036	1.000
	39.22	2247	1.008	1.000	1.010	1.000	1.010	1.000	1.038	1.000
neos-1337307	3600.00	306352	1.000	0.991	1.000	0.993	1.000	0.994	1.000	0.993
	3600.00	269284	1.000	0.998	1.000	0.979	1.000	1.002	1.000	0.952
	3600.00	349832	1.000	0.970	1.000	0.996	1.000	0.996	1.000	0.991
	3600.00	301363	1.000	0.989	1.000	0.978	1.000	**0.932**	1.000	1.006
	3600.00	373217	1.000	0.995	1.000	0.991	1.000	0.983	1.000	0.986
neos-1601936	2033.50	1453	0.999	1.000	0.994	1.000	0.999	1.000	0.996	1.000
	3600.00	2861	1.000	0.996	1.000	1.001	1.000	1.000	1.000	1.000
	1338.93	2661	1.013	1.000	1.006	1.000	1.008	1.000	1.009	1.000
	3600.00	6917	1.000	1.004	1.000	1.000	1.000	0.990	1.000	0.999
	3600.00	6139	1.000	1.000	1.000	0.977	1.000	1.000	1.000	1.010
neos-686190	83.27	4906	0.996	1.000	1.002	1.000	0.995	1.000	0.996	1.000
	86.55	6047	1.000	1.000	1.013	1.000	0.997	1.000	1.000	1.000
	115.34	9156	0.995	1.000	0.994	1.000	1.021	1.000	1.006	1.000
	117.19	9998	0.995	1.000	1.006	1.000	0.992	1.000	0.996	1.000
	120.84	9806	1.008	1.000	0.998	1.000	1.003	1.000	1.007	1.000
neos-849702	207.98	1169	*1.979*	*8.256*	*6.088*	*54.068*	*2.833*	*25.153*	*4.876*	*14.426*
	1025.85	6328	**0.139**	**0.049**	**0.772**	*1.387*	**0.158**	**0.594**	0.999	1.000
	1001.35	10499	**0.904**	**0.400**	**0.181**	**0.099**	**0.686**	*5.053*	1.016	1.000
	267.07	683	*2.864*	*2.388*	*2.815*	*9.508*	**0.763**	*13.476*	*5.812*	*84.398*
	285.44	1596	*1.679*	*1.538*	*1.067*	**0.353**	**0.470**	*4.297*	*5.308*	*35.870*
neos-934278	3600.00	1175	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.006
	3600.00	267	1.000	0.995	1.000	1.008	1.000	1.000	1.000	0.995
	3600.00	263	1.000	1.000	1.000	1.008	1.000	0.983	1.000	1.008
	3600.00	401	1.000	0.992	1.000	0.994	1.000	0.992	1.000	0.994
	3600.00	522	1.000	0.998	1.000	0.998	1.000	1.000	1.000	0.997
neos18	8.13	79	*1.234*	*1.078*	*2.113*	*3.598*	*1.604*	*2.369*	*2.852*	*4.073*
	24.87	828	1.043	*1.054*	*1.347*	*1.815*	*1.232*	*1.531*	0.999	1.028
	28.94	1095	*1.089*	1.000	**0.883**	0.965	**0.680**	**0.362**	**0.689**	**0.585**
	15.42	386	1.001	0.965	*1.107*	*1.091*	*1.161*	**0.872**	*2.091*	*2.175*
	21.77	963	0.961	**0.949**	*1.249*	*1.147*	**0.928**	**0.710**	*1.281*	**0.871**
ns1208400	938.01	3025	**0.912**	**0.753**	**0.543**	**0.314**	**0.763**	**0.692**	1.017	1.032

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Table C.4: Computational results on MMM-IP: Impact of transferred information.

Instance	degeneracy		variablebounds		conflicts		infervals		primsols	
	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	2737.49	11477	**0.667**	**0.375**	**0.269**	**0.100**	**0.220**	**0.081**	1.005	1.000
	532.73	1719	*1.828*	*1.341*	**0.710**	**0.800**	*1.579*	**0.825**	*2.439*	*2.687*
	253.07	599	*2.316*	*2.724*	*1.530*	*1.409*	*1.318*	**0.720**	*2.093*	*2.482*
	1316.58	2660	*1.221*	*1.112*	*1.259*	*2.671*	**0.330**	**0.303**	1.015	1.000
ns1688347	51.67	437	*1.239*	*1.255*	1.025	*1.220*	*1.103*	**0.719**	0.998	1.000
	42.42	203	*1.423*	*2.165*	*1.332*	*2.370*	*1.406*	*2.670*	*1.886*	*4.353*
	161.82	3095	*1.050*	**0.752**	**0.833**	**0.552**	*1.111*	**0.556**	1.003	1.000
	133.50	1251	**0.878**	**0.597**	0.964	**0.638**	1.049	*1.245*	1.008	1.000
	51.48	399	**0.948**	**0.890**	*1.378*	*2.481*	0.953	*1.156*	*1.274*	*1.691*
ns1830653	133.08	6918	0.993	1.000	0.998	1.000	0.994	1.000	0.995	1.000
	123.87	5226	0.999	1.000	0.997	1.000	*1.061*	1.000	1.007	1.000
	161.00	9597	1.004	1.000	1.001	1.000	1.001	1.000	1.007	1.000
	143.21	7435	*1.054*	1.000	1.005	1.000	0.995	1.000	1.002	1.000
	146.08	9194	1.000	1.000	1.004	1.000	1.007	1.000	1.002	1.000
nsrand-ipx	419.85	50124	1.006	1.000	1.005	1.000	1.007	1.000	1.001	1.000
	638.54	86869	1.002	1.000	1.005	1.000	0.999	1.000	1.005	1.000
	569.66	56575	0.994	1.000	1.003	1.000	1.005	1.000	1.004	1.000
	582.34	61056	1.004	1.000	1.001	1.000	1.000	1.000	1.002	1.000
	363.56	38012	1.007	1.000	1.002	1.000	1.002	1.000	1.000	1.000
opt1217	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
p0033	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
p0201	0.54	5	1.006	1.000	1.013	1.000	1.019	1.000	1.000	1.000
	0.74	9	0.989	1.000	1.000	1.000	0.983	1.000	1.011	1.000
	1.64	5	1.000	1.000	1.004	1.000	0.985	1.000	0.996	1.000
	0.90	13	1.000	1.000	1.000	1.000	1.000	1.000	1.011	1.000
	0.89	59	1.005	1.000	1.005	1.000	1.011	1.000	1.016	1.000
p0282	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	3	1.000	1.000	1.000	1.000	1.007	1.000	1.000	1.000
	0.50	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
p0548	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	0.50	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
p2756	2.51	5	0.991	1.000	0.989	1.000	1.000	1.000	0.994	1.000
	3.33	5	1.009	1.000	1.005	1.000	1.009	1.000	1.007	1.000
	2.13	3	0.994	1.000	0.990	1.000	0.987	1.000	1.006	1.000
	2.54	3	1.000	1.000	1.008	1.000	1.006	1.000	1.014	1.000
	1.28	2	1.000	1.000	0.996	1.000	1.004	1.000	1.009	1.000
protfold	3600.00	3244	1.000	**0.823**	1.000	**0.632**	1.000	*2.305*	1.000	*1.328*
	3600.00	2504	1.000	**0.715**	1.000	0.988	1.000	*2.045*	1.000	0.950
	3600.00	2755	1.000	**0.858**	1.000	*1.160*	1.000	*1.907*	1.000	**0.733**
	3600.00	1831	1.000	*1.278*	1.000	*1.551*	1.000	*2.081*	1.000	*1.256*
	3600.00	1867	1.000	**0.814**	1.000	*1.325*	1.000	*1.584*	1.000	**0.831**
pw-myciel4	3600.00	361131	1.000	*1.253*	**0.383**	**0.439**	1.000	*1.320*	1.000	*1.077*
	3600.00	365865	1.000	1.039	1.000	**0.895**	1.000	*1.253*	1.000	*1.054*
	3600.00	323450	1.000	*1.199*	1.000	*1.102*	1.000	*1.294*	1.000	*1.161*
	3600.00	358151	1.000	1.020	1.000	**0.856**	1.000	*1.395*	**0.925**	*1.097*
	3054.26	378549	*1.179*	**0.843**	*1.179*	*1.128*	*1.179*	1.019	*1.179*	**0.893**
qnet1	4.54	33	1.002	1.000	0.998	1.000	1.002	1.000	1.005	1.000
	3.12	3	0.995	1.000	1.007	1.000	1.002	1.000	0.993	1.000
	3.92	29	1.002	1.000	0.996	1.000	0.996	1.000	1.006	1.000

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Table C.4: Computational results on MMM-IP: Impact of transferred information.

	degeneracy		variablebounds		conflicts		infervals		primsols	
Instance	T	N	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q	T_Q	N_Q
	2.26	3	0.991	1.000	0.991	1.000	0.994	1.000	0.991	1.000
	3.71	34	0.994	1.000	1.002	1.000	0.996	1.000	0.987	1.000
qnet1_o	3.87	27	1.012	1.000	1.002	1.000	1.010	1.000	1.008	1.000
	3.38	24	1.000	1.000	0.995	1.000	0.995	1.000	1.002	1.000
	3.39	15	0.995	1.000	1.000	1.000	0.993	1.000	1.000	1.000
	1.67	2	1.000	1.000	1.000	1.000	0.993	1.000	1.004	1.000
	1.84	3	1.000	1.000	1.007	1.000	1.000	1.000	1.007	1.000
reblock67	223.13	49530	0.998	1.000	0.995	1.000	0.995	1.000	0.989	1.000
	161.91	40625	1.001	1.000	1.004	1.000	1.006	1.000	1.019	1.000
	194.68	49882	1.002	1.000	1.006	1.000	0.999	1.000	1.032	1.000
	200.17	50996	1.006	1.000	1.001	1.000	0.992	1.000	0.995	1.000
	239.14	57566	1.017	1.000	0.999	1.000	1.002	1.000	0.999	1.000
rmine6	971.59	111047	0.997	1.000	1.002	1.000	0.999	1.000	1.003	1.000
	882.29	89213	0.999	1.000	1.040	1.000	1.013	1.000	1.026	1.000
	776.69	91530	0.992	1.000	1.000	1.000	1.004	1.000	1.021	1.000
	742.25	85429	1.010	1.000	1.001	1.000	1.005	1.000	1.000	1.000
	773.39	76017	0.995	1.000	1.002	1.000	1.013	1.000	0.995	1.000
rococoC10-001000	603.64	46983	0.995	1.000	0.997	1.000	0.994	1.000	0.995	1.000
	836.01	75156	0.999	1.000	0.998	1.000	0.998	1.000	1.007	1.000
	516.72	37178	*1.052*	1.000	1.006	1.000	1.003	1.000	1.006	1.000
	893.05	51410	0.999	1.000	1.006	1.000	1.004	1.000	1.001	1.000
	1048.40	66016	1.004	1.000	1.010	1.000	1.008	1.000	1.003	1.000
seymour	3600.00	102192	1.000	1.003	1.000	1.002	1.000	1.007	1.000	1.000
	3600.00	120186	1.000	1.002	1.000	0.996	1.000	1.000	1.000	1.000
	3600.00	123015	1.000	1.003	1.000	0.997	1.000	0.997	1.000	0.990
	3600.00	108085	1.000	1.001	1.000	0.996	1.000	0.998	1.000	0.995
	3600.00	97046	1.000	1.001	1.000	0.994	1.000	0.999	1.000	1.001
sp98ir	58.06	3948	0.999	1.000	0.997	1.000	1.000	1.000	0.999	1.000
	65.95	4178	1.039	1.000	1.003	1.000	1.012	1.000	1.006	1.000
	67.93	4735	1.000	1.000	1.029	1.000	1.020	1.000	1.014	1.000
	72.47	4603	1.003	1.000	1.005	1.000	1.003	1.000	1.011	1.000
	69.87	4780	*1.063*	1.000	0.998	1.000	1.001	1.000	1.013	1.000
stein27	1.17	2749	0.972	1.000	1.014	1.000	1.023	1.000	0.995	1.000
	1.23	2699	1.000	1.000	0.969	1.000	0.996	1.000	0.978	1.000
	1.19	2889	0.995	1.000	1.018	1.000	1.014	1.000	1.023	1.000
	1.13	2873	0.953	1.000	0.958	1.000	0.962	**0.947**	1.014	1.000
	1.08	2827	1.019	1.000	1.010	1.000	1.014	1.029	0.990	1.000
stein45	12.59	39175	0.994	1.000	0.989	1.000	0.996	1.039	0.997	1.000
	12.49	38805	1.004	1.000	1.005	1.000	1.024	1.005	1.003	1.000
	13.04	41279	1.005	1.000	1.024	1.000	0.998	1.016	1.004	1.000
	12.49	38104	1.006	1.000	1.004	1.000	0.980	0.985	1.004	1.000
	13.02	40755	1.008	1.000	0.997	1.000	1.009	0.994	0.994	1.000
tanglegram2	4.11	3	1.002	1.000	1.006	1.000	0.990	1.000	1.000	1.000
	3.90	3	1.022	1.000	0.994	1.000	1.014	1.000	1.016	1.000
	4.20	3	1.012	1.000	1.008	1.000	1.015	1.000	1.008	1.000
	4.12	3	1.020	1.000	1.008	1.000	1.008	1.000	1.016	1.000
	4.20	3	1.000	1.000	1.000	1.000	1.038	1.000	1.000	1.000

Appendix D

Conflict-Driven Heuristics in Mixed Integer Programming

- Table D.1 illustrates the impact of Farkas Diving (`farkdiving`) as described in Section 6.3 compared to SCIP with default configuration (`default`). The table shows the number of feasible and improving solutions (**F**, **I**) and conflict constraints (**C**) found by `farkdiving`. In addition, the tables shows the number of feasible/improving solutions and conflict constraints ($\mathbf{F}_{\mathbf{virt}}$, $\mathbf{I}_{\mathbf{virt}}$, $\mathbf{C}_{\mathbf{virt}}$) found by the virtual best diving heuristic.
- Table D.2 illustrates the impact of Conflict Diving as described in Section 6.4 compared to SCIP with Coefficient Diving, i.e., SCIPs default configuration, and SCIP any of these two heuristics (`nolockdiving`). The table shows the number of feasible (**F**), conflict constraints (**C**), and average diving depth ($\mathbf{D}_{\emptyset}$).

Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
10teams	17.27	395	0	0	136	15.01	**0.876**	152	**0.509**	0	0	0
	17.04	867	0	0	209	18.77	*1.096*	927	*1.062*	0	0	0
	3.36	5	0	0	0	4.09	*1.167*	5	1.000	0	0	0
	16.01	404	0	0	64	14.80	**0.929**	187	**0.569**	0	0	0
22433	2.16	3	0	0	0	2.13	0.991	3	1.000	0	0	2
	3.15	4	0	0	0	3.27	1.029	4	1.000	0	0	2
	1.92	3	0	0	0	1.93	1.003	3	1.000	0	0	4
	4.06	26	0	0	32	4.67	*1.121*	33	*1.056*	0	0	5
23588	3.99	495	0	0	0	3.93	0.988	495	1.000	0	0	0
	4.18	535	0	0	0	3.89	**0.944**	514	0.967	0	0	0
	4.83	730	0	0	0	4.07	**0.870**	457	**0.671**	0	0	0
	3.99	563	0	0	0	4.07	1.016	563	1.000	0	0	0
30n20b8	340.50	227	2	2	30	161.68	**0.476**	181	**0.859**	0	0	1
	249.12	144	2	2	16	241.17	0.968	131	**0.947**	0	0	1
	221.49	174	1	1	38	372.21	*1.677*	405	*1.843*	0	0	1
	547.76	331	1	2	66	519.74	**0.949**	540	*1.485*	0	0	1
Test3	4.24	4	0	0	0	5.35	*1.212*	4	1.000	0	0	0
	4.20	3	0	0	0	5.28	*1.208*	3	1.000	0	0	0
	4.23	2	0	0	0	4.34	1.021	2	1.000	1	1	0
	3.80	1	0	0	0	4.97	*1.244*	1	1.000	0	0	0
a1c1s1	limit	203191	6	6	19	limit	1.000	188432	**0.927**	1	1	57
	limit	205820	0	11	12	limit	1.000	242015	*1.176*	0	0	52
	limit	222398	0	2	22	limit	1.000	199956	**0.899**	0	0	27
	limit	189340	4	1	14	limit	1.000	181197	0.957	0	0	19
acc-tight5	101.89	744	0	0	257	101.71	0.998	744	1.000	0	0	0
	49.41	159	0	0	58	49.23	0.996	159	1.000	0	0	0
	156.63	1168	0	0	276	157.76	1.007	1168	1.000	0	0	0
	93.91	645	0	0	199	93.89	1.000	645	1.000	0	0	0
aflow30a	21.13	873	0	0	0	21.45	1.014	463	**0.579**	0	0	11
	18.03	503	0	0	0	13.39	**0.756**	486	0.972	0	0	2
	19.58	582	0	0	0	19.09	0.976	560	0.968	0	0	2
	13.67	715	0	0	0	16.65	*1.203*	636	**0.903**	0	0	2
aflow40b	704.70	24637	0	0	111	485.49	**0.689**	16932	**0.689**	0	0	10
	567.41	19980	0	0	133	511.81	**0.902**	15291	**0.766**	0	0	10
	543.12	22701	0	0	99	593.42	*1.092*	25469	*1.121*	0	0	10
	378.71	9715	0	0	130	260.18	**0.688**	11525	*1.184*	0	0	8
air03	1.75	1	0	0	0	1.70	0.982	1	1.000	1	1	0
	1.71	1	0	0	0	1.70	0.996	1	1.000	1	1	0
	1.75	1	0	0	0	1.76	1.004	1	1.000	1	1	0
	1.76	1	0	0	0	1.71	0.982	1	1.000	1	1	0
air04	39.64	110	0	0	0	47.32	*1.189*	91	**0.910**	0	0	0
	49.27	192	0	0	15	60.46	*1.223*	289	*1.332*	0	0	0
	38.34	107	0	0	6	48.96	*1.270*	211	*1.502*	0	0	0
	58.58	315	0	0	4	49.75	**0.852**	204	**0.733**	0	0	0
air05	36.56	798	0	0	4	26.78	**0.740**	364	**0.517**	0	0	0
	35.50	743	0	0	0	29.32	**0.831**	378	**0.567**	0	0	0
	26.98	422	0	0	0	24.64	**0.916**	249	**0.669**	0	0	0
	23.33	160	0	0	0	32.30	*1.369*	503	*2.319*	0	0	0
aligninq	31.31	3320	0	0	2475	35.11	*1.118*	3699	*1.111*	0	0	0
	27.55	2875	0	0	1783	33.04	*1.192*	22	**0.041**	0	0	0
	22.01	1700	0	0	1726	26.68	*1.203*	2731	*1.573*	0	0	0
	28.58	3044	0	0	834	15.42	**0.555**	569	**0.213**	0	0	0
app1-2	811.69	26	0	0	0	614.05	**0.757**	26	1.000	0	0	0
	721.53	26	0	0	0	545.76	**0.757**	26	1.000	0	0	0
	1004.06	42	0	0	0	803.09	**0.800**	42	1.000	0	0	0
	848.25	20	0	0	0	631.76	**0.745**	20	1.000	0	0	0
arki001	limit	1201140	0	0	69	limit	1.000	1201509	1.000	0	0	0
	limit	1211984	1	1	222	limit	1.000	1217612	1.005	0	0	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	1092636	0	0	112	limit	1.000	1093059	1.000	0	0	0
	limit	1271142	1	2	102	limit	1.000	1274901	1.003	0	0	0
ash608gpia-3col	32.16	5	0	0	0	31.93	0.993	5	1.000	0	0	0
	26.94	11	0	0	0	26.89	0.998	11	1.000	0	0	0
	17.71	3	0	0	0	17.89	1.010	3	1.000	0	0	0
	26.33	11	0	0	0	26.32	1.000	11	1.000	0	0	0
atlanta-ip	limit	15522	0	0	2687	limit	1.000	16380	*1.055*	0	0	30
	limit	14243	0	0	1529	limit	1.000	17842	*1.251*	0	0	0
	limit	13595	0	0	1738	limit	1.000	10374	**0.765**	0	0	0
	limit	12701	0	0	1447	limit	1.000	16427	*1.291*	0	0	0
bab5	limit	87901	0	0	3135	limit	1.000	84925	0.966	0	0	262
	limit	108867	0	0	561	limit	1.000	109488	1.006	0	0	2
	limit	101859	1	1	796	3806.15	**0.529**	59960	**0.589**	0	0	31
	limit	84402	0	0	336	5724.17	**0.795**	75557	**0.895**	0	0	72
bc1	218.41	3870	1	1	0	219.01	1.003	3870	1.000	0	0	0
	196.52	4006	0	0	2	197.02	1.003	4006	1.000	0	0	0
	170.93	1600	0	0	0	169.57	0.992	1600	1.000	0	0	0
	179.18	3422	0	0	1	179.66	1.003	3422	1.000	0	0	0
bc	830.83	11703	0	0	11	823.31	0.991	11703	1.000	0	0	0
	915.83	11588	0	0	22	899.84	0.983	11588	1.000	0	0	0
	850.19	13849	0	0	10	840.49	0.989	13849	1.000	0	0	0
	839.69	13103	0	0	3	830.57	0.989	13103	1.000	0	0	0
beasleyC3	45.85	378	0	0	1	41.76	**0.913**	352	**0.946**	122	0	14
	54.14	515	1	0	5	25.94	**0.489**	2	**0.166**	109	0	25
	44.79	170	0	0	0	21.82	**0.498**	2	**0.378**	128	0	63
	16.53	2	0	0	0	19.37	*1.162*	2	1.000	39	0	8
bell3a	0.70	2445	15	0	19	1.33	*1.371*	4756	*1.908*	11	0	1
	0.62	2184	12	0	27	1.52	*1.556*	5762	*2.567*	11	0	1
	0.83	3116	15	0	30	1.65	*1.448*	5707	*1.806*	11	0	1
	0.81	2720	15	0	27	1.67	*1.475*	5731	*2.068*	11	0	1
bell5	0.50	444	28	0	133	0.50	1.000	277	**0.693**	17	1	11
	0.50	339	18	0	10	0.50	1.000	395	*1.128*	43	6	5
	0.50	196	24	1	22	0.50	1.000	291	*1.321*	40	3	32
	0.50	451	28	0	144	0.50	1.000	126	**0.410**	36	1	11
biella1	1249.94	8151	1	1	109	1254.30	1.003	4893	**0.605**	0	0	0
	948.57	5091	0	1	58	474.64	**0.501**	1746	**0.356**	0	0	0
	821.51	1975	0	0	310	778.18	**0.947**	3326	*1.651*	0	0	0
	1016.26	4551	0	0	296	458.95	**0.452**	1489	**0.342**	0	0	0
bienst1	121.81	16090	3	3	39	122.54	1.006	16090	1.000	0	0	0
	95.33	9901	1	1	20	95.30	1.000	9901	1.000	0	0	0
	98.50	9304	1	1	53	98.75	1.003	9304	1.000	0	0	0
	115.57	15248	1	1	28	116.17	1.005	15248	1.000	0	0	0
bienst2	516.44	62497	4	4	21	519.88	1.007	62497	1.000	0	0	0
	586.82	81035	0	0	11	588.93	1.004	81035	1.000	0	0	0
	471.76	62789	2	2	23	474.68	1.006	62789	1.000	0	0	0
	455.83	60072	1	3	11	458.68	1.006	60072	1.000	0	0	0
binkar10_1	25.43	2435	1	1	12	21.85	**0.865**	1867	**0.776**	1	1	34
	37.03	2686	0	0	26	41.13	*1.108*	3693	*1.361*	1	1	137
	21.76	1927	2	2	18	34.29	*1.551*	2654	*1.359*	1	1	152
	35.34	4380	1	1	34	33.82	0.958	3972	**0.909**	1	1	224
blend2	0.83	706	0	0	13	0.85	1.011	728	1.027	0	0	2
	0.91	832	1	1	14	1.21	*1.157*	1026	*1.208*	1	1	19
	0.75	635	0	0	10	0.80	1.029	757	*1.166*	0	0	10
	0.77	592	0	0	9	0.73	0.977	700	*1.156*	0	0	2
bley_xl1	164.90	1	0	0	0	167.76	1.017	2	1.010	2	2	0
	194.10	28	0	0	0	195.60	1.008	42	*1.109*	1	1	0
	131.54	1	0	0	0	132.77	1.009	1	1.000	1	1	5
	132.98	1	0	0	0	134.60	1.012	1	1.000	1	1	0
bnatt350	679.89	4220	0	0	693	683.46	1.005	4220	1.000	0	0	0
	846.32	7468	0	0	1277	851.82	1.006	7468	1.000	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	426.02	4560	0	0	891	428.83	1.007	4560	1.000	0	0	0
	417.21	3663	1	0	757	420.42	1.008	3663	1.000	0	0	0
cap6000	2.87	1978	15	0	65	3.39	*1.134*	2014	1.017	66	0	74
	2.65	1668	12	1	66	3.66	*1.277*	2486	*1.463*	67	0	69
	3.10	2113	20	0	51	3.66	*1.137*	2205	1.042	64	0	100
	3.18	2086	22	1	50	3.09	0.978	1646	**0.799**	63	0	97
core2536-691	131.38	118	0	0	0	124.10	**0.945**	95	**0.894**	0	0	0
	126.70	174	0	0	4	387.82	*3.045*	260	*1.314*	0	0	0
	95.65	60	0	0	0	106.07	*1.108*	63	1.019	0	0	0
	100.59	126	1	1	0	141.06	*1.398*	113	**0.942**	0	0	0
cov1075	61.82	19799	0	0	23	62.02	1.003	19799	1.000	0	0	0
	83.76	32317	4	1	63	83.27	0.994	32317	1.000	0	0	0
	47.84	13662	13	1	37	47.95	1.002	13662	1.000	0	0	0
	71.04	23085	21	2	50	70.94	0.999	23085	1.000	0	0	0
csched010	5858.01	317482	0	1	183	4796.30	**0.819**	260919	**0.822**	0	0	48
	limit	440703	0	0	234	5114.71	**0.710**	288748	**0.655**	0	0	159
	3337.23	216270	0	0	221	3077.06	**0.922**	173514	**0.802**	0	0	97
	4633.71	263158	1	1	312	2817.09	**0.608**	160928	**0.612**	0	0	29
d10200	limit	1081637	0	0	31	limit	1.000	1265884	*1.170*	0	0	3
	limit	929088	0	0	53	limit	1.000	1118124	*1.203*	0	0	0
	limit	922480	0	0	34	limit	1.000	1024016	*1.110*	0	0	3
	limit	1028189	0	0	25	limit	1.000	1159438	*1.128*	0	0	0
d20200	limit	382717	0	0	138	limit	1.000	292381	**0.764**	0	0	0
	limit	328751	0	0	105	limit	1.000	421069	*1.281*	0	0	0
	limit	292099	0	0	120	limit	1.000	326181	*1.117*	0	0	0
	limit	333054	0	0	43	limit	1.000	287782	**0.864**	0	0	0
dano3_3	127.48	18	1	1	0	127.45	1.000	18	1.000	0	0	0
	103.61	6	0	0	0	102.92	0.993	6	1.000	0	0	0
	114.70	14	0	0	0	113.60	0.990	14	1.000	0	0	0
	112.43	12	0	0	0	111.19	0.989	12	1.000	0	0	0
dano3_4	149.72	14	0	0	0	149.79	1.000	14	1.000	0	0	0
	142.90	8	0	0	0	141.79	0.992	8	1.000	0	0	0
	131.13	14	0	0	1	130.60	0.996	14	1.000	0	0	0
	110.46	29	0	0	1	110.37	0.999	29	1.000	0	0	0
dano3_5	311.35	185	1	1	4	309.24	0.993	185	1.000	0	0	0
	324.73	156	1	1	7	324.00	0.998	156	1.000	0	0	0
	281.32	132	2	2	2	281.38	1.000	132	1.000	0	0	0
	300.10	176	2	2	2	298.72	0.995	176	1.000	0	0	0
dano3mip	limit	2117	0	0	11	limit	1.000	2034	0.963	0	0	0
	limit	1563	0	0	7	limit	1.000	1378	**0.889**	0	0	0
	limit	1019	0	0	4	limit	1.000	1011	0.993	0	0	0
	limit	2264	0	0	2	limit	1.000	2299	1.015	0	0	0
danoint	3938.60	1425342	3	3	0	3953.66	1.004	1425342	1.000	0	0	0
	3677.23	1364472	0	0	7	3673.95	0.999	1364472	1.000	0	0	0
	3369.80	1195273	2	2	6	3374.95	1.002	1195273	1.000	0	0	0
	2924.24	1062058	0	0	3	2927.95	1.001	1062058	1.000	0	0	0
dcmulti	2.67	52	0	0	0	1.73	**0.744**	81	*1.191*	0	0	7
	2.70	71	0	0	0	3.15	*1.122*	157	*1.503*	0	0	5
	2.05	69	0	0	0	1.94	0.964	12	**0.663**	0	0	0
	2.22	82	0	0	0	1.51	**0.780**	118	*1.198*	1	1	14
dfn-gwin-UUM	143.10	39424	87	8	13	89.58	**0.629**	21399	**0.544**	103	5	27
	96.16	24607	106	7	98	82.05	**0.855**	19496	**0.793**	112	2	12
	121.80	32723	98	4	16	127.31	1.045	34489	*1.054*	91	4	22
	96.94	23175	92	4	18	96.34	0.994	25789	*1.112*	99	5	23
disctom	5.49	1	0	0	0	5.44	0.992	1	1.000	0	0	0
	5.88	1	0	0	0	5.86	0.997	1	1.000	0	0	0
	4.75	1	0	0	0	4.71	0.993	1	1.000	0	0	0
	7.43	1	0	0	0	7.42	0.999	1	1.000	0	0	0
ds	limit	826	54	2	26	limit	1.000	1190	*1.393*	19	0	0
	limit	1239	56	4	25	limit	1.000	1203	0.973	66	2	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	1101	59	3	19	limit	1.000	740	**0.699**	20	0	10
	limit	917	41	2	16	limit	1.000	636	**0.724**	23	0	89
dsbmip	1.56	16	0	0	0	1.61	1.020	16	1.000	0	0	0
	1.24	27	1	1	0	1.25	1.004	27	1.000	0	0	0
	1.39	16	0	0	0	1.39	1.000	16	1.000	0	0	0
	1.66	14	0	0	0	1.66	1.000	14	1.000	0	0	0
egout	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	2
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	2
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	2
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	2
eil33-2	76.61	653	0	0	0	62.38	**0.817**	603	**0.934**	2	1	0
	66.79	665	0	0	0	81.77	*1.221*	741	*1.099*	2	1	0
	75.19	677	0	0	0	64.87	**0.865**	517	**0.794**	1	1	0
	80.46	629	0	0	0	63.02	**0.786**	603	0.964	2	1	0
eilB101	466.60	13787	4	0	13	327.23	**0.702**	9255	**0.674**	5	1	8
	432.96	10965	0	0	71	461.51	*1.066*	12556	*1.144*	4	0	39
	375.87	10774	5	0	14	528.13	*1.404*	16616	*1.537*	5	1	69
	497.08	15515	0	0	38	343.99	**0.693**	10412	**0.673**	5	1	8
enigma	0.50	215	0	0	0	0.50	1.000	664	*2.425*	0	0	0
	0.50	580	0	0	6	0.50	1.000	657	*1.113*	0	0	0
	0.50	946	0	0	3	0.50	1.000	514	**0.587**	0	0	4
	0.52	1485	0	0	12	0.50	0.987	940	**0.656**	0	0	0
enlight13	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
enlight14	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
ex9	27.49	1	0	0	0	27.17	0.989	1	1.000	0	0	0
	26.39	1	0	0	0	26.36	0.999	1	1.000	0	0	0
	27.06	1	0	0	0	26.83	0.992	1	1.000	0	0	0
	26.37	1	0	0	0	25.87	0.982	1	1.000	0	0	0
fast0507	268.91	1067	11	0	4	148.86	**0.555**	726	**0.708**	26	0	5
	168.78	667	9	0	1	166.87	0.989	839	*1.224*	26	0	8
	160.64	737	15	0	1	136.65	**0.852**	618	**0.858**	34	0	5
	192.30	930	20	0	3	221.89	*1.153*	1065	*1.131*	25	0	43
fiball	1741.07	4050	0	2	80	1760.37	1.011	4050	1.000	0	0	0
	limit	18110	2	2	485	limit	1.000	17854	0.986	0	0	0
	2368.37	5996	1	1	64	2413.69	1.019	5996	1.000	0	0	0
	1553.82	3686	1	1	25	1568.42	1.009	3686	1.000	0	0	0
fiber	2.16	5	0	0	0	2.38	*1.070*	5	1.000	0	0	8
	1.93	4	0	0	0	2.26	*1.113*	5	1.010	0	0	2
	2.08	4	0	0	0	2.42	*1.110*	4	1.000	0	0	7
	2.04	6	0	0	0	2.71	*1.220*	7	1.009	0	0	0
fixnet6	4.48	3	0	0	0	5.31	*1.151*	4	1.010	34	1	8
	5.82	4	0	0	0	5.26	**0.918**	3	0.990	22	0	13
	6.18	4	0	0	0	4.83	**0.812**	3	0.990	24	0	4
	4.55	3	0	0	0	4.61	1.011	2	0.990	23	0	4
flugpl	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
gen	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
germanrr	limit	12182	2	2	204	limit	1.000	14337	*1.175*	0	0	0
	limit	5221	0	0	96	limit	1.000	3483	**0.673**	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	12091	4	4	290	limit	1.000	9630	**0.798**	0	0	0
	limit	3398	3	3	219	limit	1.000	13344	*3.843*	0	0	0
gesa2-o	0.65	4	0	0	0	0.69	1.024	3	0.990	0	0	81
	0.90	2	0	0	0	0.94	1.021	2	1.000	0	0	73
	0.50	2	0	0	0	0.60	*1.067*	1	0.990	1	1	10
	0.59	2	0	0	0	0.71	*1.075*	2	1.000	1	1	3
gesa2	0.50	2	0	0	0	0.54	1.027	2	1.000	1	1	0
	0.50	2	0	0	0	0.50	1.000	2	1.000	1	1	0
	0.50	2	0	0	0	0.56	1.040	2	1.000	1	1	0
	0.50	2	0	0	0	0.53	1.020	2	1.000	1	1	0
gesa3	6.82	10	0	0	0	5.53	**0.835**	7	0.973	1	1	58
	6.08	6	0	0	0	3.87	**0.688**	4	0.981	0	0	47
	5.48	7	0	0	0	5.72	1.037	6	0.991	1	1	98
	5.03	6	0	0	0	9.86	*1.801*	8	1.019	1	1	81
gesa3_o	2.08	6	0	0	0	2.16	1.026	6	1.000	0	0	24
	2.19	8	0	0	0	6.19	*2.254*	8	1.000	0	0	31
	2.80	7	0	0	0	5.19	*1.629*	7	1.000	0	0	30
	2.19	6	0	0	0	3.33	*1.357*	5	0.991	1	1	33
glass4	1081.60	697512	0	0	800	1047.28	0.968	670375	0.961	0	0	0
	4441.62	3510870	1	2	1749	limit	*1.621*	5416705	*1.543*	0	0	0
	1018.60	986169	2	2	1809	1021.67	1.003	986169	1.000	0	0	0
	589.30	580186	2	4	1871	590.84	1.003	580186	1.000	0	0	0
gmu-35-40	limit	4475349	1	0	64	limit	1.000	5169683	*1.155*	1	1	184
	limit	6071632	0	0	52	limit	1.000	4400930	**0.725**	0	0	17
	limit	5794844	0	0	40	limit	1.000	5248675	**0.906**	0	0	4
	limit	4848137	0	0	33	limit	1.000	4032850	**0.832**	2	2	88
gt2	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
haprp	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
iis-100-0-cov	571.64	103091	3	0	75	574.94	1.006	103091	1.000	0	0	0
	512.51	92475	3	0	85	513.36	1.002	92475	1.000	0	0	0
	463.04	81601	0	0	90	467.13	1.009	81601	1.000	0	0	0
	491.93	86709	6	1	111	493.53	1.003	86709	1.000	0	0	0
iis-bupa-cov	1737.89	156016	3	0	192	1744.78	1.004	156016	1.000	0	0	0
	1774.24	160860	1	1	365	1778.46	1.002	160860	1.000	0	0	0
	1950.35	187396	3	0	258	1962.08	1.006	187396	1.000	0	0	0
	1721.79	157506	5	0	178	1725.33	1.002	157506	1.000	0	0	0
iis-pima-cov	372.15	9246	3	0	18	372.74	1.002	9246	1.000	0	0	0
	374.04	10062	2	0	20	374.86	1.002	10062	1.000	0	0	0
	277.55	6479	1	0	31	279.58	1.007	6479	1.000	0	0	0
	498.03	15737	0	0	30	500.16	1.004	15737	1.000	0	0	0
khb05250	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	0
	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	0
	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	0
	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	0
l152lav	2.31	33	0	0	0	3.19	*1.266*	49	*1.120*	0	0	16
	2.25	43	0	0	0	1.83	**0.871**	25	**0.874**	0	0	0
	2.20	39	0	0	0	2.15	0.984	16	**0.835**	0	0	6
	1.92	30	0	0	0	3.47	*1.531*	77	*1.362*	0	0	0
lectsched-4-obj	31.57	1104	1	1	30	30.49	0.967	1224	*1.100*	0	0	4
	60.50	857	2	2	174	29.41	**0.494**	973	*1.121*	2	2	17
	8.55	5	0	0	0	7.54	**0.894**	5	1.000	0	0	4
	39.21	2136	2	2	110	65.62	*1.657*	7311	*3.314*	1	1	24
leo1	limit	114869	2	0	3	limit	1.000	89316	**0.778**	0	0	0
	limit	65297	1	0	0	limit	1.000	129148	*1.976*	0	0	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	109229	1	0	4	limit	1.000	64189	**0.588**	0	0	0
	limit	139996	0	0	0	limit	1.000	76236	**0.545**	0	0	0
leo2	limit	109748	0	0	0	limit	1.000	89667	**0.817**	0	0	0
	limit	109121	0	0	0	limit	1.000	92145	**0.845**	0	0	0
	limit	102556	0	0	0	limit	1.000	99259	0.968	0	0	0
	limit	98198	0	0	0	limit	1.000	91019	**0.927**	0	0	0
liu	limit	2132229	70	70	561	limit	1.000	2238428	1.050	0	0	0
	limit	2168465	67	67	551	limit	1.000	2149401	0.991	0	0	0
	limit	2234022	82	82	468	limit	1.000	2198433	0.984	0	0	0
	limit	2010953	83	83	591	limit	1.000	2684713	*1.335*	0	0	0
lrn	limit	2849	1	1	23	limit	1.000	5809	*2.004*	0	0	0
	limit	3108	0	1	27	limit	1.000	3392	*1.089*	0	0	4
	limit	2433	2	3	23	limit	1.000	2398	0.986	0	0	0
	limit	4428	5	5	33	limit	1.000	3111	**0.709**	0	0	0
lseu	0.55	176	0	0	0	0.50	0.968	124	**0.812**	0	0	10
	0.50	4	0	0	0	0.50	1.000	4	1.000	0	0	13
	0.50	68	0	0	0	0.50	1.000	68	1.000	0	0	13
	0.61	275	0	0	8	0.53	0.950	288	1.035	0	0	14
m100n500k4r1	limit	5602256	0	0	17	limit	1.000	5612513	1.002	0	0	0
	limit	4665776	0	0	75	limit	1.000	4659469	0.999	0	0	0
	limit	4605152	0	0	21	limit	1.000	4611341	1.001	0	0	0
	limit	4799358	0	0	12	limit	1.000	4816893	1.004	0	0	0
macrophage	123.97	5034	0	0	33	126.83	1.023	5469	*1.085*	0	0	0
	156.71	6177	1	1	13	150.32	0.959	6359	1.029	0	0	0
	145.36	6176	0	0	63	126.80	**0.873**	5068	**0.823**	0	0	0
	124.77	5602	0	1	19	126.21	1.011	5602	1.000	0	0	0
manna81	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
map18	234.06	249	0	0	8	242.24	1.035	247	0.994	0	0	0
	270.00	273	0	0	3	304.82	*1.128*	265	0.979	0	0	0
	237.94	305	0	0	4	277.52	*1.166*	287	0.956	0	0	0
	240.69	231	0	0	7	266.78	*1.108*	337	*1.320*	0	0	0
map20	187.86	392	0	0	2	226.43	*1.204*	215	**0.640**	0	0	0
	240.53	237	0	0	6	247.41	1.028	225	0.964	0	0	0
	212.14	406	0	0	2	168.84	**0.797**	229	**0.650**	0	0	0
	209.69	247	0	0	4	171.16	**0.817**	243	0.988	0	0	0
markshare1	limit	46601329	2	1	15	limit	1.000	47115567	1.011	25	0	33
	limit	43212995	2	1	20	limit	1.000	44982538	1.041	23	0	28
	limit	42811231	2	1	26	limit	1.000	42497217	0.993	24	0	46
	limit	47699801	3	1	13	limit	1.000	47578221	0.997	23	0	18
markshare2	limit	17973492	5	1	19	limit	1.000	17683844	0.984	28	0	28
	limit	18763219	3	1	20	limit	1.000	17365176	**0.925**	26	1	24
	limit	18191301	6	1	23	limit	1.000	19912112	*1.095*	29	0	32
	limit	19059341	5	1	28	limit	1.000	17202854	**0.903**	27	0	32
mas74	1488.71	6027541	0	0	147	1491.63	1.002	6027541	1.000	0	0	0
	1995.54	6950287	0	0	134	2001.89	1.003	6950287	1.000	0	0	0
	1737.12	7071228	0	0	123	1732.05	0.997	7071228	1.000	0	0	0
	1730.58	6843504	0	0	121	1727.84	0.998	6843504	1.000	0	0	0
mas76	70.31	198417	0	0	498	70.13	0.997	198417	1.000	0	0	0
	110.89	360101	0	0	383	110.00	0.992	360101	1.000	0	0	0
	85.17	246746	0	0	490	85.43	1.003	246746	1.000	0	0	0
	83.58	209149	0	0	506	83.97	1.005	209149	1.000	0	0	0
mcsched	181.82	7120	0	0	55	191.96	*1.055*	7989	*1.120*	0	0	0
	201.08	8226	0	0	65	234.68	*1.166*	9207	*1.118*	0	0	1
	282.00	13747	0	0	83	219.96	**0.781**	9432	**0.688**	0	0	0
	158.33	6145	0	0	61	255.70	*1.611*	10827	*1.750*	0	0	0
mik-250-1-100-1	64.83	22968	0	0	89	52.86	**0.818**	21582	**0.940**	32	0	164
	38.86	15147	2	0	37	39.91	1.026	16857	*1.112*	49	0	78

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	66.98	23266	4	0	104	45.03	**0.677**	17607	**0.758**	23	0	128
	100.62	34844	3	0	81	40.55	**0.409**	13152	**0.379**	41	0	128
mine-166-5	61.37	276	0	0	0	57.26	**0.934**	2077	*5.790*	1	1	163
	66.58	2802	2	2	38	68.70	1.031	147	**0.085**	3	3	141
	46.54	2538	1	1	81	58.00	*1.241*	2207	**0.875**	1	1	58
	48.36	1615	1	1	15	50.99	*1.053*	1461	**0.910**	1	1	132
mine-90-10	397.37	38513	0	0	1066	228.35	**0.576**	26592	**0.691**	1	1	178
	180.22	25651	1	1	1253	203.20	*1.127*	32629	*1.271*	2	2	213
	342.60	47767	2	2	2447	168.55	**0.493**	23014	**0.483**	2	2	332
	691.71	76187	1	1	2896	261.14	**0.378**	34052	**0.448**	1	1	208
misc03	0.50	11	0	0	0	0.70	*1.133*	52	*1.369*	0	0	0
	0.78	23	0	0	0	0.83	1.028	20	0.976	1	1	0
	0.50	7	0	0	0	0.52	1.013	17	*1.093*	0	0	0
	0.60	29	0	0	0	0.66	1.038	29	1.000	2	2	0
misc06	0.50	3	0	0	0	0.55	1.033	3	1.000	6	0	968
	0.54	3	0	0	0	0.57	1.019	3	1.000	6	0	1009
	0.50	3	0	0	0	0.53	1.020	3	1.000	7	1	1034
	0.50	3	0	0	0	0.50	1.000	3	1.000	6	0	963
misc07	10.23	6065	0	0	166	13.19	*1.264*	8257	*1.356*	0	0	6
	11.80	6097	0	0	133	12.15	1.027	7163	*1.172*	0	0	3
	12.29	7615	0	0	288	7.98	**0.676**	4102	**0.545**	0	0	2
	8.84	5035	0	0	35	6.69	**0.782**	2116	**0.432**	1	1	3
mitre	10.12	1	0	0	0	10.14	1.002	1	1.000	1	1	0
	10.45	1	0	0	0	10.24	0.982	1	1.000	1	1	0
	10.49	1	0	0	0	10.23	0.977	1	1.000	1	1	0
	12.95	1	0	0	0	12.96	1.001	1	1.000	0	0	0
mkc1	2816.11	951305	1	1	123	41.73	**0.015**	2925	**0.003**	0	0	0
	limit	2126006	1	1	50	126.57	**0.018**	18349	**0.009**	1	1	29
	89.67	12288	1	1	10	41.04	**0.464**	2868	**0.240**	1	1	0
	limit	2621298	0	0	61	limit	1.000	2845839	*1.086*	1	1	0
mkc	limit	737537	0	0	329	limit	1.000	597914	**0.811**	2	2	2701
	limit	608454	0	0	395	limit	1.000	497382	**0.817**	1	1	1851
	limit	618101	1	1	411	limit	1.000	608311	0.984	2	2	2547
	limit	682691	0	0	367	limit	1.000	617531	**0.905**	1	1	2696
mod008	0.94	1	0	0	0	0.94	1.000	1	1.000	1	0	3
	0.96	1	0	0	0	0.95	0.995	1	1.000	2	0	3
	0.94	1	0	0	0	0.96	1.010	1	1.000	1	0	2
	0.89	1	0	0	0	0.87	0.989	1	1.000	0	0	0
mod010	0.50	2	0	0	0	0.50	1.000	2	1.000	1	1	0
	0.50	2	0	0	0	0.50	1.000	2	1.000	1	1	0
	0.50	2	0	0	0	0.54	1.027	3	1.010	1	1	4
	0.60	2	0	0	0	0.50	**0.938**	2	1.000	1	1	0
mod011	336.25	586	3	3	0	330.93	0.984	626	*1.058*	0	0	0
	511.54	683	3	3	0	493.73	0.965	653	0.962	0	0	0
	167.42	1419	2	2	0	167.92	1.003	1419	1.000	0	0	0
	336.08	738	1	1	0	373.91	*1.112*	1120	*1.456*	0	0	0
modglob	0.50	2	0	0	0	0.50	1.000	2	1.000	8	0	21
	0.50	2	0	0	0	0.50	1.000	2	1.000	8	0	54
	0.50	2	0	0	0	0.50	1.000	2	1.000	18	1	4
momentum1	limit	23896	0	0	66	limit	1.000	46779	*1.954*	0	0	0
	limit	42136	0	0	93	limit	1.000	81768	*1.938*	0	0	35
	limit	24245	0	0	77	limit	1.000	80402	*3.307*	0	0	2
	limit	18972	0	0	92	limit	1.000	152184	*7.985*	0	0	0
momentum3	limit	243	1	1	200	limit	1.000	570	*1.953*	0	0	0
	limit	366	1	1	202	limit	1.000	230	**0.708**	0	0	0
	limit	282	0	0	307	limit	1.000	357	*1.196*	0	0	0
	limit	1094	0	0	267	limit	1.000	983	**0.907**	0	0	0
msc98-ip	limit	8532	0	0	4472	7027.21	0.976	14585	*1.701*	0	0	0
	limit	4483	0	0	2338	4577.10	**0.636**	4399	0.982	0	0	71
	limit	6076	0	0	3057	limit	1.000	3900	**0.648**	0	0	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	8715	0	0	573	limit	1.000	35111	*3.994*	0	0	17
mspp16	409.35	3	0	0	0	412.94	1.009	3	1.000	0	0	0
	405.27	5	0	0	0	409.43	1.010	5	1.000	0	0	0
	395.29	5	0	0	0	395.41	1.000	5	1.000	0	0	0
	362.75	5	0	0	0	369.61	1.019	5	1.000	0	0	0
mzzv11	310.00	2672	0	0	10	453.95	*1.463*	2738	1.024	0	0	76
	371.60	2212	2	2	94	293.67	**0.791**	1599	**0.735**	0	0	53
	340.88	2189	0	0	79	311.13	**0.913**	1265	**0.596**	0	0	62
	306.76	1922	2	2	32	268.35	**0.875**	714	**0.403**	0	0	5
mzzv42z	130.46	174	1	1	1	175.77	*1.345*	321	*1.536*	1	1	0
	170.99	309	1	1	10	138.30	**0.810**	251	**0.858**	1	1	10
	154.50	214	0	0	14	159.45	1.032	285	*1.226*	1	1	3
	185.92	514	1	1	18	138.17	**0.745**	86	**0.303**	0	0	14
n3div36	limit	208470	0	0	16	limit	1.000	213284	1.023	0	0	0
	limit	218756	0	0	19	limit	1.000	225280	1.030	0	0	0
	limit	217735	0	0	8	limit	1.000	236538	*1.086*	0	0	0
	limit	200146	0	0	13	limit	1.000	209559	1.047	0	0	0
n3seq24	limit	362	2	2	0	limit	1.000	2332	*5.264*	0	0	0
	limit	4324	2	2	25	limit	1.000	1512	**0.364**	3	3	99
	limit	888	2	2	0	limit	1.000	355	**0.461**	0	0	0
	limit	2734	1	1	12	limit	1.000	1583	**0.594**	0	0	0
n4-3	180.34	2929	34	11	83	215.22	*1.192*	3479	*1.182*	62	0	39
	230.02	2886	116	19	40	165.48	**0.721**	2039	**0.716**	62	0	18
	191.70	2706	87	10	24	223.04	*1.163*	3166	*1.164*	23	0	51
	212.68	3225	36	5	26	235.73	*1.108*	3427	*1.061*	107	0	67
nag	limit	68926	2	2	545	limit	1.000	67430	0.978	0	0	0
	limit	90913	1	2	205	limit	1.000	88916	0.978	0	0	0
	limit	141677	0	0	257	limit	1.000	138712	0.979	0	0	0
	limit	37277	0	1	176	limit	1.000	36570	0.981	0	0	0
neos-1053234	limit	1646555	0	2	72	limit	1.000	1639786	0.996	0	0	0
	6643.16	2451273	0	1	47	6650.19	1.001	2451273	1.000	0	0	0
	1901.37	385298	0	1	21	1901.91	1.000	385298	1.000	0	0	0
	2330.07	589638	0	1	24	2329.99	1.000	589638	1.000	0	0	0
neos-1053591	4.26	2493	1	1	11	4.20	0.989	2493	1.000	0	0	0
	2.49	1568	2	2	12	2.53	1.011	1568	1.000	0	0	0
	2.43	1364	2	2	7	2.36	0.980	1364	1.000	0	0	0
	18.38	19713	1	1	109	18.43	1.003	19713	1.000	0	0	0
neos-1056905	limit	14633767	1	1	1211	limit	1.000	14682549	1.003	0	0	0
	limit	7653724	0	1	2261	limit	1.000	7644848	0.999	0	0	0
	limit	16831677	1	4	461	limit	1.000	16857054	1.002	0	0	0
	limit	13013959	0	2	1453	limit	1.000	12949736	0.995	0	0	0
neos-1058477	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.72	1	0	0	0	0.74	1.012	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-1061020	311.42	1553	1	1	41	181.94	**0.586**	935	**0.626**	1	1	0
	332.57	1699	0	0	35	370.39	*1.113*	1957	*1.143*	1	1	0
	226.36	835	0	0	39	205.68	**0.909**	956	*1.129*	1	1	0
	189.87	857	0	0	42	255.93	*1.346*	1316	*1.480*	0	0	0
neos-1062641	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-1067731	limit	242959	0	0	138	limit	1.000	176962	**0.728**	0	0	0
	limit	225966	0	1	125	limit	1.000	285653	*1.264*	0	0	0
	limit	249809	0	0	92	limit	1.000	249584	0.999	0	0	0
	limit	189160	0	0	97	limit	1.000	213739	*1.130*	0	0	0
neos-1096528	1660.08	3228	0	0	36	2000.88	*1.205*	3840	*1.184*	0	0	0
	1403.23	1052	0	0	0	1647.22	*1.174*	4379	*3.888*	0	0	0
	1212.74	1698	0	0	9	1770.95	*1.460*	4662	*2.648*	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	1599.43	3715	0	0	46	1920.50	*1.201*	4052	*1.088*	0	0	0
neos-1109824	11.20	110	0	0	0	11.27	1.006	67	**0.795**	0	0	0
	13.43	114	0	0	0	16.35	*1.202*	202	*1.411*	1	1	0
	16.15	145	0	0	6	35.45	*2.125*	1072	*4.784*	0	0	0
	10.90	64	0	0	0	12.30	*1.118*	89	*1.152*	0	0	0
neos-1120495	5.60	21	0	0	0	27.62	*4.336*	24	1.025	2	2	0
	4.51	8	0	0	0	5.32	*1.147*	12	1.037	0	0	0
	8.07	16	0	0	0	8.23	1.018	13	0.974	1	1	0
	4.36	3	0	0	0	6.72	*1.440*	12	*1.087*	1	1	6
neos-1121679	limit	46380871	2	1	15	limit	1.000	47024932	1.014	25	0	33
	limit	43103074	2	1	20	limit	1.000	44942990	1.043	23	0	28
	limit	43028673	2	1	26	limit	1.000	42455083	0.987	24	0	46
	limit	47465488	3	1	13	limit	1.000	47640023	1.004	23	0	18
neos-1122047	5.99	1	0	0	0	6.05	1.009	1	1.000	0	0	0
	5.88	1	0	0	0	6.16	1.041	1	1.000	0	0	0
	5.99	1	0	0	0	5.99	1.000	1	1.000	0	0	0
	6.05	1	0	0	0	6.06	1.001	1	1.000	0	0	0
neos-1126860	473.85	4681	1	1	44	533.03	*1.125*	4641	0.992	0	0	0
	460.78	4431	0	0	34	496.18	*1.077*	4471	1.009	0	0	0
	483.69	4090	1	1	37	492.29	1.018	4462	*1.089*	0	0	0
	483.31	4175	0	0	45	477.53	0.988	4426	*1.059*	0	0	0
neos-1151496	18.04	89	0	0	0	17.97	0.996	89	1.000	0	0	0
	16.50	64	0	0	0	16.57	1.004	64	1.000	0	0	0
	2.38	1	0	0	0	2.34	0.988	1	1.000	0	0	0
	27.58	81	0	0	0	27.48	0.997	81	1.000	0	0	0
neos-1171448	8.60	1	0	0	0	8.67	1.007	1	1.000	0	0	0
	62.63	120	0	0	0	63.02	1.006	120	1.000	0	0	0
	8.63	1	0	0	0	8.68	1.005	1	1.000	0	0	0
	59.60	89	1	1	0	59.76	1.003	89	1.000	0	0	0
neos-1171692	29.06	241	0	0	0	29.00	0.998	241	1.000	0	0	0
	831.98	271	0	0	16	832.66	1.001	271	1.000	0	0	0
	4.05	1	0	0	0	4.06	1.002	1	1.000	0	0	0
	73.81	38	0	0	0	73.65	0.998	38	1.000	0	0	0
neos-1171737	limit	3961	0	0	147	limit	1.000	3966	1.001	0	0	0
	limit	4691	0	0	253	limit	1.000	4727	1.008	0	0	0
	limit	4420	0	0	113	limit	1.000	4420	1.000	0	0	0
	limit	9169	0	0	228	limit	1.000	9043	0.986	0	0	0
neos-1173026	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-1200887	12.26	7621	0	0	18	12.39	1.010	7621	1.000	0	0	0
	7.36	2934	1	1	16	7.36	1.000	2934	1.000	0	0	0
	19.16	11880	0	0	40	19.21	1.002	11880	1.000	0	0	0
	9.10	3646	0	0	20	9.18	1.008	3646	1.000	0	0	0
neos-1208069	116.96	2294	0	0	633	116.89	0.999	2294	1.000	0	0	0
	41.17	784	0	0	157	41.40	1.005	784	1.000	0	0	0
	197.93	7099	2	2	3861	196.86	0.995	7099	1.000	0	0	0
	77.12	2881	1	1	856	76.89	0.997	2881	1.000	0	0	0
neos-1208135	335.90	10513	1	1	910	335.73	0.999	10513	1.000	0	0	0
	329.17	2838	0	0	181	328.94	0.999	2838	1.000	0	0	0
	327.41	10535	0	0	971	328.83	1.004	10535	1.000	0	0	0
	283.91	2554	0	0	1094	284.69	1.003	2554	1.000	0	0	0
neos-1211578	5.27	10174	0	0	82	5.20	0.989	10174	1.000	0	0	0
	1.60	1363	0	0	28	1.59	0.996	1363	1.000	0	0	0
	3.43	5493	2	0	104	3.48	1.011	5493	1.000	0	0	0
	4.24	7782	1	1	100	4.32	1.015	7782	1.000	0	0	0
neos-1215259	45.11	1123	0	0	201	90.40	*1.982*	2785	*2.359*	0	0	124
	50.92	1337	0	0	421	66.61	*1.302*	1781	*1.309*	0	0	61
	52.81	1577	0	0	191	42.64	**0.811**	1113	**0.723**	0	0	275

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	68.96	2353	0	0	158	88.52	*1.280*	2403	1.020	0	0	106
neos-1215891	492.44	4997	1	1	292	492.97	1.001	4997	1.000	0	0	0
	255.26	3221	0	0	22	253.26	0.992	3221	1.000	0	0	0
	407.19	3240	1	1	246	407.51	1.001	3240	1.000	0	0	0
	410.01	3148	1	0	169	412.15	1.005	3148	1.000	0	0	0
neos-1223462	146.71	67	0	1	0	214.54	*1.459*	1134	*7.389*	0	0	0
	331.00	565	0	1	39	132.90	**0.403**	111	**0.317**	0	0	0
	142.06	155	0	0	0	693.26	*4.853*	317	*1.635*	0	0	3
	193.50	705	0	0	80	154.42	**0.799**	426	**0.653**	0	0	0
neos-1224597	18.94	21	0	0	0	18.98	1.002	21	1.000	0	0	0
	0.85	1	0	0	0	0.87	1.011	1	1.000	0	0	0
	49.30	102	0	0	0	48.72	0.988	102	1.000	0	0	0
	1.75	1	0	0	0	1.76	1.004	1	1.000	0	0	0
neos-1228986	11.32	22116	0	0	509	11.55	1.019	22116	1.000	0	0	0
	23.23	58746	0	0	538	23.21	0.999	58746	1.000	0	0	0
	52.49	179182	0	0	1084	52.95	1.009	179182	1.000	0	0	0
	18.61	48140	2	2	574	18.52	0.995	48140	1.000	0	0	0
neos-1281048	3.35	10	0	0	0	7.72	*2.005*	44	*1.309*	0	0	0
	8.14	162	0	0	0	7.10	**0.886**	43	**0.546**	0	0	0
	7.02	56	0	0	0	7.76	*1.092*	103	*1.301*	0	0	0
	5.03	28	0	0	0	5.61	*1.096*	26	0.984	1	1	0
neos-1311124	limit	14645631	0	0	16774	limit	1.000	14613786	0.998	0	0	0
	limit	15038041	0	0	4872	limit	1.000	15060089	1.001	0	0	0
	limit	14284657	0	0	7668	limit	1.000	14270301	0.999	0	0	0
	limit	14619461	0	0	8770	limit	1.000	14725675	1.007	0	0	0
neos-1324574	2080.79	16740	0	0	102	2090.79	1.005	16740	1.000	0	0	0
	2186.74	21201	0	0	77	2181.34	0.998	21201	1.000	0	0	0
	172.30	1212	0	0	40	172.60	1.002	1212	1.000	0	0	0
	1426.97	12780	0	0	58	1422.54	0.997	12780	1.000	0	0	0
neos-1330346	3921.77	212094	0	0	6459	3964.11	1.011	212094	1.000	0	0	0
	4521.94	241604	0	0	9858	4594.02	1.016	241604	1.000	0	0	0
	5812.06	277273	0	0	1196	5920.02	1.019	277273	1.000	0	0	0
	4264.04	228558	0	0	6336	4317.54	1.013	228558	1.000	0	0	0
neos-1330635	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-1337307	limit	643977	0	0	4415	limit	1.000	692428	*1.075*	0	0	11
	limit	693098	0	1	3695	limit	1.000	683201	0.986	0	0	21
	limit	774320	0	0	4539	limit	1.000	724936	**0.936**	0	0	0
	limit	753673	0	0	6384	limit	1.000	763306	1.013	1	1	6810
neos-1346382	limit	14640661	0	1	61000	limit	1.000	14660959	1.001	0	0	0
	limit	12331646	0	0	146074	limit	1.000	12249392	0.993	0	0	0
	limit	14822038	0	2	53300	limit	1.000	14727394	0.994	0	0	0
	limit	14447459	0	0	63134	limit	1.000	14458847	1.001	0	0	0
neos-1354092	limit	439	0	0	17	limit	1.000	450	1.020	0	0	0
	limit	2978	0	0	8	limit	1.000	2983	1.002	0	0	0
	limit	221	0	0	7	limit	1.000	224	1.009	0	0	0
	limit	1328	0	0	9	limit	1.000	1334	1.004	0	0	0
neos-1367061	22.35	1	0	0	0	22.46	1.005	1	1.000	0	0	0
	24.51	1	0	0	0	24.93	1.016	1	1.000	1	1	0
	23.66	1	0	0	0	23.12	0.978	1	1.000	1	1	0
	24.15	1	0	0	0	24.37	1.009	1	1.000	0	0	0
neos-1396125	131.60	15392	0	0	74	132.33	1.006	15392	1.000	0	0	0
	99.70	8226	0	0	145	100.02	1.003	8226	1.000	0	0	0
	97.23	10313	0	0	70	97.03	0.998	10313	1.000	0	0	0
	123.36	12053	0	0	134	124.01	1.005	12053	1.000	0	0	0
neos-1407044	limit	102	0	0	0	limit	1.000	88	**0.931**	0	0	0
	limit	105	0	0	0	limit	1.000	87	**0.912**	0	0	0
	limit	114	0	0	0	limit	1.000	116	1.009	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	119	0	0	0	limit	1.000	117	0.991	0	0	0
neos-1413153	4.38	3	0	0	0	4.39	1.002	3	1.000	0	0	0
	2.61	2	0	0	0	2.63	1.006	2	1.000	0	0	0
	2.83	2	0	0	0	2.87	1.010	2	1.000	0	0	0
	2.51	2	0	0	0	2.56	1.014	2	1.000	0	0	0
neos-1415183	5.04	2	0	0	0	5.07	1.005	2	1.000	0	0	0
	4.94	2	0	0	0	4.93	0.998	2	1.000	0	0	0
	5.66	2	0	0	0	5.68	1.003	2	1.000	0	0	0
	3.89	1	0	0	0	3.93	1.008	1	1.000	0	0	0
neos-1417043	1250.03	1	0	0	0	1255.25	1.004	1	1.000	0	0	0
	1099.79	1	0	0	0	1103.84	1.004	1	1.000	0	0	0
	1163.21	1	0	0	0	1171.08	1.007	1	1.000	0	0	0
	1085.23	1	0	0	0	1089.83	1.004	1	1.000	0	0	0
neos-1420205	3.41	4297	0	0	62	5.10	*1.383*	8283	*1.907*	1	1	59
	3.73	4342	0	0	59	4.47	*1.156*	7565	*1.726*	1	1	58
	5.26	8626	0	0	61	1.83	**0.452**	1792	**0.217**	1	1	14
	3.07	3874	0	0	23	4.08	*1.248*	8118	*2.068*	1	1	45
neos-1420546	limit	7831	1	1	0	limit	1.000	7856	1.003	0	0	0
	limit	7430	2	2	0	limit	1.000	7484	1.007	0	0	0
	limit	3216	4	4	0	limit	1.000	3289	1.022	0	0	0
	limit	4446	2	2	0	limit	1.000	4491	1.010	0	0	0
neos-1420790	limit	197700	1	1	35	limit	1.000	196923	0.996	0	0	0
	limit	191449	2	2	128	limit	1.000	191418	1.000	0	0	0
	limit	150487	0	1	55	limit	1.000	149227	0.992	0	0	0
	limit	134663	1	1	45	limit	1.000	134760	1.001	0	0	0
neos-1423785	limit	14100	2	9	52	limit	1.000	14027	0.995	0	0	0
	limit	59381	1	2	36	limit	1.000	58821	0.991	0	0	0
	limit	60026	2	3	66	limit	1.000	59709	0.995	0	0	0
	limit	50727	3	3	66	limit	1.000	50617	0.998	0	0	0
neos-1425699	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-1426662	limit	5947614	0	1	811	limit	1.000	5897984	0.992	0	0	0
	limit	6899009	1	1	6060	limit	1.000	6913304	1.002	0	0	0
	limit	7399300	1	1	3670	limit	1.000	7390569	0.999	0	0	0
	limit	4870068	1	1	452	limit	1.000	4869160	1.000	0	0	0
neos-1427181	3870.56	1573037	0	1	641	3875.17	1.001	1573037	1.000	0	0	0
	3938.40	4245564	0	1	693	3909.49	0.993	4245564	1.000	0	0	0
	2198.86	1890627	0	1	1480	2201.77	1.001	1890627	1.000	0	0	0
	798.57	874110	0	1	1175	804.50	1.007	874110	1.000	0	0	0
neos-1427261	limit	1259210	0	1	541	limit	1.000	1259898	1.001	0	0	0
	limit	3536029	0	1	597	limit	1.000	3537779	1.000	0	0	0
	limit	1418328	1	1	598	limit	1.000	1420959	1.002	0	0	0
	limit	1205587	0	2	440	limit	1.000	1207186	1.001	0	0	0
neos-1429185	limit	6916557	1	1	948	limit	1.000	6905764	0.998	0	0	0
	limit	6885239	1	2	1256	limit	1.000	6876518	0.999	0	0	0
	limit	7444713	0	1	448	limit	1.000	7440269	0.999	0	0	0
	limit	6351090	0	1	889	limit	1.000	6345027	0.999	0	0	0
neos-1429212	limit	19929	0	0	708	limit	1.000	6798	**0.344**	0	0	0
	limit	7361	0	0	615	limit	1.000	15212	*2.052*	0	0	0
	limit	7115	0	0	599	limit	1.000	14027	*1.958*	0	0	1034
	limit	6171	0	0	291	limit	1.000	7763	*1.254*	0	0	1
neos-1429461	limit	8496708	0	1	41268	limit	1.000	8535308	1.005	0	0	0
	limit	9388586	0	1	29661	limit	1.000	9387432	1.000	0	0	0
	limit	8028032	0	0	58048	limit	1.000	8040670	1.002	0	0	0
	limit	7841233	0	0	37913	limit	1.000	7868992	1.004	0	0	0
neos-1430701	23.56	31119	1	1	300	23.50	0.998	31119	1.000	0	0	0
	15.35	16303	1	1	200	15.58	1.014	16303	1.000	0	0	0
	20.36	26433	1	1	326	20.34	0.999	26433	1.000	0	0	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	10.32	11121	0	0	134	10.42	1.009	11121	1.000	0	0	0
neos-1430811	limit	1932	0	0	187	limit	1.000	1922	0.995	0	0	0
	limit	2458	0	0	87	limit	1.000	1778	**0.734**	0	0	0
	limit	1706	0	0	96	limit	1.000	1632	0.959	0	0	0
	limit	2004	0	0	199	limit	1.000	1296	**0.663**	0	0	0
neos-1436709	limit	5177811	0	1	7365	limit	1.000	5185081	1.001	0	0	0
	limit	4762881	0	0	6413	limit	1.000	4775806	1.003	0	0	0
	limit	4680225	0	2	11536	limit	1.000	4699088	1.004	0	0	0
	limit	4381548	0	0	12417	limit	1.000	4384711	1.001	0	0	0
neos-1436713	limit	1610386	0	0	316	limit	1.000	1607621	0.998	0	0	0
	limit	2283099	1	1	607	limit	1.000	2292543	1.004	0	0	0
	limit	3087919	0	1	327	limit	1.000	3091994	1.001	0	0	0
	limit	1639695	0	1	200	limit	1.000	1636532	0.998	0	0	0
neos-1437164	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.77	2	0	0	0	0.78	1.006	2	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-1439395	109.01	193227	0	0	1133	109.59	1.005	193227	1.000	0	0	0
	496.36	969820	0	1	3176	497.50	1.002	969820	1.000	0	0	0
	85.64	155192	1	1	877	86.46	1.009	155192	1.000	0	0	0
	190.46	366979	0	0	1193	190.07	0.998	366979	1.000	0	0	0
neos-1440225	26.68	1345	0	0	10	26.73	1.002	1345	1.000	0	0	0
	59.72	3402	0	0	7	59.57	0.998	3402	1.000	0	0	0
	4.03	3	0	0	0	4.00	0.994	3	1.000	0	0	0
	13.01	259	0	0	0	13.02	1.001	259	1.000	0	0	0
neos-1440447	5.69	5142	1	1	83	5.81	1.018	5142	1.000	0	0	0
	2.68	2105	0	1	35	2.68	1.000	2105	1.000	0	0	0
	7.82	8147	0	0	125	7.95	1.015	8147	1.000	0	0	0
	2.36	1249	0	0	32	2.35	0.997	1249	1.000	0	0	0
neos-1440457	limit	3872132	1	0	9089	limit	1.000	3863522	0.998	0	0	0
	limit	3137794	0	1	7947	limit	1.000	3145887	1.003	0	0	0
	limit	4028854	0	2	10828	limit	1.000	4016999	0.997	0	0	0
	limit	4295613	0	1	8866	limit	1.000	4290690	0.999	0	0	0
neos-1440460	2623.88	4260679	0	0	10447	2620.24	0.999	4260679	1.000	0	0	0
	limit	10592036	1	1	23851	limit	1.000	10619516	1.003	0	0	0
	limit	9545303	0	1	25148	limit	1.000	9571410	1.003	0	0	0
	limit	8748365	1	1	37532	limit	1.000	8742852	0.999	0	0	0
neos-1441553	1.93	1	0	0	0	1.96	1.010	1	1.000	0	0	0
	2.27	2	0	0	0	2.29	1.006	2	1.000	0	0	0
	3.26	2	0	0	0	3.24	0.995	2	1.000	0	0	0
	1.99	5	0	0	0	2.03	1.013	5	1.000	0	0	0
neos-1442119	limit	3788616	0	1	14129	limit	1.000	3787695	1.000	0	0	0
	limit	3330697	3	3	7995	limit	1.000	3326248	0.999	0	0	0
	limit	3226636	0	1	10086	limit	1.000	3228595	1.001	0	0	0
	limit	3308843	0	1	6830	limit	1.000	3310502	1.001	0	0	0
neos-1442657	limit	4452761	0	0	17667	limit	1.000	4449489	0.999	0	0	0
	limit	3879737	2	2	11811	limit	1.000	3874540	0.999	0	0	0
	limit	5124114	0	0	15337	limit	1.000	5121976	1.000	0	0	0
	limit	4694436	1	1	24337	limit	1.000	4705617	1.002	0	0	0
neos-1445532	limit	2435	1	1	174	limit	1.000	844	**0.372**	0	0	0
	limit	676	1	3	240	limit	1.000	791	*1.148*	0	0	0
	limit	1055	1	1	101	limit	1.000	780	**0.762**	0	0	0
	limit	1808	1	1	169	limit	1.000	2156	*1.182*	0	0	0
neos-1445738	limit	30471	7	7	1279	limit	1.000	27148	**0.891**	0	0	0
	limit	23925	2	2	1715	limit	1.000	19632	**0.821**	0	0	0
	limit	19225	3	3	1288	limit	1.000	21533	*1.119*	0	0	0
	limit	37639	5	5	969	limit	1.000	25237	**0.671**	0	0	0
neos-1445743	45.92	3	0	0	0	48.08	1.046	3	1.000	9	3	0
	52.66	3	0	0	0	54.17	1.028	3	1.000	0	0	8
	45.04	3	0	0	0	45.52	1.010	3	1.000	9	3	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	53.76	3	0	0	0	57.18	*1.062*	3	1.000	0	0	12
neos-1445755	51.90	3	0	0	0	55.01	*1.059*	4	1.010	6	1	4
	48.79	3	0	0	0	49.18	1.008	3	1.000	7	3	2
	49.54	3	0	0	0	52.48	*1.058*	4	1.010	6	1	19
	57.24	4	0	0	0	56.88	0.994	4	1.000	7	3	58
neos-1445765	56.44	86	0	0	0	53.30	**0.945**	71	**0.919**	7	1	0
	68.91	3	0	0	0	74.04	*1.073*	5	1.019	8	1	116
	81.97	7	0	0	0	79.17	0.966	6	0.991	8	1	28
	55.31	91	0	0	0	56.40	1.019	100	1.047	7	1	0
neos-1451294	467.88	886	1	0	283	468.19	1.001	886	1.000	0	0	0
	2759.38	5972	0	1	357	2767.24	1.003	5972	1.000	0	0	0
	870.93	2965	0	1	443	864.60	0.993	2965	1.000	0	0	0
	1318.81	5308	1	1	622	1319.88	1.001	5308	1.000	0	0	0
neos-1456979	limit	103430	0	0	1340	limit	1.000	34288	**0.332**	0	0	29
	limit	41406	1	1	1165	limit	1.000	51588	*1.245*	0	0	74
	2582.73	120347	0	0	1492	limit	*2.787*	40272	**0.335**	0	0	38
	limit	42995	0	0	983	limit	1.000	41370	0.962	1	1	678
neos-1460246	limit	5751347	0	2	2112	limit	1.000	5736271	0.997	0	0	0
	limit	4577903	0	0	871	limit	1.000	4550782	0.994	0	0	0
	limit	5006491	1	1	1208	limit	1.000	5008710	1.000	0	0	0
	limit	5907155	1	1	1524	limit	1.000	5892480	0.998	0	0	0
neos-1460265	5.26	60	0	0	1	5.29	1.005	60	1.000	0	0	0
	4.72	94	0	0	7	4.76	1.007	94	1.000	0	0	0
	2.27	1	0	0	0	2.28	1.003	1	1.000	0	0	0
	3.63	42	0	0	0	3.68	1.011	42	1.000	0	0	0
neos-1460543	limit	22845	0	0	87	limit	1.000	22711	0.994	0	0	0
	limit	25965	0	0	60	limit	1.000	25694	0.990	0	0	0
	limit	45415	0	0	5	limit	1.000	45291	0.997	0	0	0
	limit	19185	0	0	68	limit	1.000	18966	0.989	0	0	0
neos-1460641	limit	869368	1	1	702	limit	1.000	865275	0.995	0	0	0
	limit	804436	0	0	561	limit	1.000	798244	0.992	0	0	0
	limit	798781	0	1	692	limit	1.000	796464	0.997	0	0	0
	limit	906228	0	0	706	limit	1.000	861697	0.951	0	0	0
neos-1461051	30.98	3960	0	0	5	30.25	0.977	3960	1.000	0	0	0
	27.31	2539	0	0	0	27.62	1.011	2539	1.000	0	0	0
	35.50	4164	0	0	0	35.58	1.002	4164	1.000	0	0	0
	29.87	3816	0	0	0	30.08	1.007	3816	1.000	0	0	0
neos-1464762	limit	1127694	0	2	928	limit	1.000	1119305	0.993	0	0	0
	limit	935364	0	0	1133	limit	1.000	909520	0.972	0	0	0
	limit	510265	1	1	1966	limit	1.000	661249	*1.296*	0	0	0
	limit	876942	0	3	1641	limit	1.000	873711	0.996	0	0	0
neos-1467067	limit	11831218	0	0	19937	limit	1.000	11871751	1.003	0	0	0
	limit	13606320	0	0	26543	limit	1.000	13653803	1.003	0	0	0
	limit	11673470	0	1	23599	limit	1.000	11678480	1.000	0	0	0
	limit	13873582	0	0	42343	limit	1.000	13998455	1.009	0	0	0
neos-1467371	limit	1184553	3	3	2097	limit	1.000	1182062	0.998	0	0	0
	limit	1235852	1	1	1796	limit	1.000	1226518	0.992	0	0	0
	limit	926529	0	1	1206	limit	1.000	873380	**0.943**	0	0	0
	limit	797064	0	0	536	limit	1.000	790940	0.992	0	0	0
neos-1467467	limit	257258	0	0	296	limit	1.000	245650	0.955	0	0	0
	limit	247773	0	0	315	limit	1.000	246400	0.994	0	0	0
	limit	222217	0	0	469	limit	1.000	219277	0.987	0	0	0
	limit	225353	0	0	354	limit	1.000	223402	0.991	0	0	0
neos-1480121	2.84	8588	0	1	0	2.83	0.997	8588	1.000	0	0	0
	0.50	106	0	0	0	0.50	1.000	106	1.000	0	0	0
	12.44	207	0	0	0	12.40	0.997	207	1.000	0	0	0
	0.80	858	0	0	9	0.81	1.006	858	1.000	0	0	0
neos-1489999	2.88	30	0	0	0	2.90	1.005	31	1.008	1	1	0
	2.59	23	0	0	0	2.80	*1.058*	25	1.016	1	1	0
	2.53	31	0	0	0	2.75	*1.062*	28	0.977	1	1	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	2.90	26	0	0	0	3.06	1.041	28	1.016	1	1	0
neos-1516309	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
neos-1582420	32.19	712	0	0	11	45.60	*1.404*	1581	*2.070*	0	0	32
	25.95	460	0	0	0	26.79	1.031	362	**0.825**	0	0	0
	26.43	237	0	0	0	26.10	0.988	98	**0.588**	0	0	40
	35.35	14	0	0	0	31.20	**0.886**	43	*1.254*	0	0	16
neos-1593097	limit	63241	0	0	2408	limit	1.000	65147	1.030	1	1	2957
	limit	49184	0	0	1521	limit	1.000	68329	*1.388*	0	0	511
	limit	60249	0	0	3978	limit	1.000	61277	1.017	0	0	618
	limit	57167	0	0	2456	limit	1.000	43913	**0.769**	1	1	1144
neos-1595230	214.53	38974	0	0	202	215.42	1.004	38974	1.000	0	0	0
	310.73	63703	0	0	186	310.40	0.999	63703	1.000	0	0	0
	185.97	35227	0	0	153	186.25	1.001	35227	1.000	0	0	0
	510.32	99743	0	0	227	513.64	1.006	99743	1.000	0	0	0
neos-1597104	175.13	5	0	0	0	174.83	0.998	5	1.000	0	0	0
	172.38	5	0	0	0	170.54	0.989	5	1.000	0	0	0
	178.66	5	0	0	0	180.73	1.012	5	1.000	0	0	0
	246.51	12	0	0	0	246.88	1.001	12	1.000	0	0	0
neos-1599274	0.98	1	0	0	0	0.96	0.990	1	1.000	1	1	0
	0.86	1	0	0	0	0.87	1.005	1	1.000	1	1	0
	0.66	1	0	0	0	0.66	1.000	1	1.000	0	0	0
	0.78	1	0	0	0	0.76	0.989	1	1.000	1	1	0
neos-1601936	3106.10	5687	1	1	1143	limit	*2.318*	4881	**0.861**	0	0	0
	6143.86	8250	1	1	532	4246.90	**0.691**	9756	*1.180*	0	0	0
	4864.25	12107	1	1	1558	2492.04	**0.512**	2832	**0.240**	0	0	0
	1859.04	1106	0	0	240	5085.81	*2.735*	11361	*9.503*	0	0	0
neos-1603512	2.01	13	0	0	0	2.03	1.007	13	1.000	0	0	0
	1.68	14	0	0	0	1.72	1.015	14	1.000	0	0	0
	2.66	23	0	0	21	2.64	0.995	23	1.000	0	0	0
	1.84	11	0	0	0	1.87	1.011	11	1.000	0	0	0
neos-1603518	5.94	27	0	0	33	5.98	1.006	27	1.000	0	0	0
	6.33	31	0	0	0	6.35	1.003	31	1.000	0	0	0
	7.23	44	0	0	0	7.22	0.999	44	1.000	0	0	0
	7.09	35	0	0	39	7.05	0.995	35	1.000	0	0	0
neos-1605061	limit	1178	0	0	58	limit	1.000	1165	0.990	0	0	0
	limit	1091	0	0	384	limit	1.000	1089	0.998	0	0	0
	limit	1285	0	0	278	limit	1.000	1276	0.994	0	0	0
	limit	843	0	0	178	limit	1.000	842	0.999	0	0	0
neos-1605075	4076.49	1724	1	3	330	limit	*1.766*	6162	*3.433*	0	0	0
	5440.10	7388	0	1	629	limit	*1.323*	3506	**0.482**	0	0	0
	limit	8155	1	1	496	5787.06	**0.804**	5833	**0.719**	0	0	0
	limit	3571	0	0	398	limit	1.000	5071	*1.409*	0	0	0
neos-1616732	3107.59	1006387	0	1	0	3114.43	1.002	1006387	1.000	0	0	0
	3179.46	1126050	3	1	0	3199.12	1.006	1126050	1.000	0	0	0
	2762.90	1193963	0	0	0	2783.96	1.008	1193963	1.000	0	0	0
	2624.23	968298	0	0	0	2646.40	1.008	968298	1.000	0	0	0
neos-1620770	limit	2459278	0	0	62104	limit	1.000	2448945	0.996	0	0	0
	limit	2350565	0	0	76410	limit	1.000	2336394	0.994	0	0	0
	limit	1447381	0	0	234972	limit	1.000	1436389	0.992	0	0	0
	limit	1724673	0	0	84179	limit	1.000	1719682	0.997	0	0	0
neos-1620807	6.42	2706	0	0	126	6.46	1.005	2706	1.000	0	0	0
	4.09	665	0	0	0	4.12	1.006	665	1.000	0	0	0
	5.94	1388	0	0	196	6.08	1.020	1388	1.000	0	0	0
	6.09	355	0	0	0	6.16	1.010	355	1.000	0	0	0
neos-1622252	4044.79	1285515	0	0	146384	3949.08	0.976	1285515	1.000	0	0	0
	2099.09	716449	0	0	114361	2102.78	1.002	716449	1.000	0	0	0
	limit	1599801	0	0	937371	limit	1.000	1589798	0.994	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	2564.10	976272	0	0	206271	2604.32	1.016	976272	1.000	0	0	0
neos-430149	31.41	31870	0	0	111	31.80	1.012	31870	1.000	0	0	0
	34.99	37959	2	2	289	34.89	0.997	37959	1.000	0	0	0
	27.27	28281	0	1	98	27.13	0.995	28281	1.000	0	0	0
	26.49	25965	1	1	149	26.70	1.008	25965	1.000	0	0	0
neos-476283	140.35	405	1	1	21	139.89	0.997	405	1.000	0	0	0
	138.37	444	0	0	6	138.36	1.000	444	1.000	0	0	0
	183.43	505	0	0	12	181.95	0.992	505	1.000	0	0	0
	119.45	321	1	1	15	119.08	0.997	321	1.000	0	0	0
neos-480878	65.00	19056	46	1	186	50.27	**0.777**	14670	**0.771**	0	0	7
	47.23	9831	38	1	99	35.34	**0.753**	8222	**0.838**	0	0	7
	51.40	12219	35	0	153	26.53	**0.525**	5829	**0.481**	0	0	7
	47.89	12264	50	2	137	55.88	*1.163*	14225	*1.159*	0	0	7
neos-494568	15.20	6	0	0	0	16.82	*1.100*	6	1.000	0	0	3
	19.68	6	0	0	0	17.64	**0.901**	7	1.009	1	1	5
	19.73	6	0	0	0	21.19	*1.070*	6	1.000	1	1	3
	15.52	6	0	0	0	21.26	*1.347*	6	1.000	1	1	10
neos-495307	limit	138020	83	0	35	limit	1.000	131544	0.953	171	0	9
	limit	119134	45	0	34	limit	1.000	155698	*1.307*	165	0	31
	limit	198152	45	0	1105	limit	1.000	146853	**0.741**	220	0	13
	limit	160297	10	0	30	limit	1.000	126821	**0.791**	157	0	12
neos-498623	24.80	6	0	0	0	26.82	*1.078*	6	1.000	1	1	1
	24.84	6	0	0	0	29.26	*1.171*	6	1.000	1	1	1
	45.64	21	0	0	0	30.51	**0.676**	6	**0.876**	2	2	0
	33.52	14	0	0	0	57.58	*1.697*	16	1.018	0	0	0
neos-501453	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-501474	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	27
	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	27
	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	27
	0.58	4	0	0	0	0.50	**0.949**	4	1.000	0	0	42
neos-503737	570.93	28994	1	1	615	573.07	1.004	28994	1.000	0	0	0
	609.14	39762	1	1	1032	615.37	1.010	39762	1.000	0	0	0
	137.62	2168	1	1	1422	138.25	1.005	2168	1.000	0	0	0
	130.64	2987	0	0	224	130.96	1.002	2987	1.000	0	0	0
neos-504674	54.21	7974	3	3	63	54.06	0.997	7974	1.000	0	0	0
	46.96	9049	1	1	38	46.65	0.994	9049	1.000	0	0	0
	39.15	7268	1	1	39	38.98	0.996	7268	1.000	0	0	0
	38.19	5572	1	1	33	38.45	1.007	5572	1.000	0	0	0
neos-504815	19.49	2922	1	1	46	14.90	**0.776**	2177	**0.753**	2	2	0
	15.86	2964	1	1	10	15.88	1.001	2701	**0.914**	1	1	36
	17.44	3753	2	2	21	13.30	**0.775**	1561	**0.431**	1	1	15
	18.01	3466	1	1	19	15.87	**0.887**	2698	**0.785**	1	1	26
neos-506422	42.83	4863	0	0	42	42.95	1.003	4863	1.000	0	0	0
	62.50	5962	1	1	101	62.93	1.007	5962	1.000	0	0	0
	60.87	6295	1	1	42	60.62	0.996	6295	1.000	0	0	0
	48.02	4681	0	0	25	48.22	1.004	4681	1.000	0	0	0
neos-506428	3225.69	291	1	1	122	3246.56	1.006	291	1.000	0	0	0
	4710.66	230	1	1	138	4697.87	0.997	230	1.000	0	0	0
	5179.95	669	0	0	283	5129.74	0.990	669	1.000	0	0	0
	4184.60	494	0	0	215	4155.22	0.993	494	1.000	0	0	0
neos-512201	27.41	3009	3	3	42	27.45	1.001	3009	1.000	0	0	0
	23.41	2635	1	1	28	23.42	1.000	2635	1.000	0	0	0
	23.09	3373	2	2	29	23.21	1.005	3373	1.000	0	0	0
	22.87	2500	0	0	18	22.86	1.000	2500	1.000	0	0	0
neos-522351	1.33	1	0	0	0	1.31	0.991	1	1.000	1	1	0
	1.51	1	0	0	0	1.46	0.980	1	1.000	1	1	0
	1.23	2	0	0	0	1.55	*1.143*	2	1.000	1	1	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	0.85	1	0	0	0	0.83	0.989	1	1.000	1	1	0
neos-525149	1.89	1	0	0	0	2.95	*1.367*	1	1.000	1	1	0
	2.28	1	0	0	0	3.73	*1.442*	1	1.000	0	0	0
	2.54	2	0	0	0	2.12	**0.881**	1	0.990	1	1	0
	1.54	1	0	0	0	3.38	*1.724*	1	1.000	1	1	0
neos-530627	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-538867	68.04	23809	0	0	550	58.50	**0.862**	23137	0.972	1	1	328
	80.67	32887	0	0	140	87.88	*1.088*	29788	**0.906**	0	0	11
	54.31	27978	1	1	765	64.90	*1.191*	31065	*1.110*	1	1	391
	100.49	33245	0	0	202	49.22	**0.495**	22694	**0.684**	1	1	211
neos-538916	28.49	5488	1	1	140	37.49	*1.305*	8257	*1.496*	0	0	0
	23.08	3728	0	0	119	26.11	*1.126*	3636	0.976	0	0	0
	25.64	6245	1	1	189	18.64	**0.737**	4342	**0.700**	0	0	0
	39.98	8110	0	0	223	35.66	**0.895**	5392	**0.669**	1	1	156
neos-544324	49.95	206	0	0	0	49.87	0.998	206	1.000	0	0	0
	42.46	119	0	0	0	41.77	0.984	119	1.000	0	0	0
	40.84	54	0	0	0	40.62	0.995	54	1.000	0	0	0
	39.63	46	0	0	0	39.21	0.990	46	1.000	0	0	0
neos-547911	19.48	158	0	0	0	19.25	0.989	158	1.000	0	0	0
	17.36	133	0	0	7	17.14	0.988	133	1.000	0	0	0
	19.06	122	0	0	0	19.01	0.998	122	1.000	0	0	0
	7.19	3	0	0	0	7.18	0.999	3	1.000	0	0	0
neos-548047	limit	54698	0	0	156	limit	1.000	53434	0.977	0	0	0
	limit	50518	0	0	924	limit	1.000	49334	0.977	0	0	0
	limit	65352	0	0	651	limit	1.000	63871	0.977	0	0	0
	limit	75459	0	0	521	limit	1.000	68830	**0.912**	0	0	0
neos-548251	limit	4523067	2	2	1186	limit	1.000	4531554	1.002	0	0	0
	limit	4573160	0	1	385	limit	1.000	4604905	1.007	0	0	0
	limit	4113760	1	1	846	limit	1.000	4112987	1.000	0	0	0
	limit	4178753	0	1	370	limit	1.000	4164813	0.997	0	0	0
neos-551991	131.70	615	0	0	293	133.25	1.012	615	1.000	0	0	0
	98.36	665	0	0	215	99.20	1.008	665	1.000	0	0	0
	137.35	575	0	0	99	138.85	1.011	575	1.000	0	0	0
	259.39	1527	0	0	116	261.25	1.007	1527	1.000	0	0	0
neos-555001	1.04	1	0	0	0	2.17	*1.554*	1	1.000	0	0	12
	0.67	1	0	0	0	8.05	*5.419*	383	*4.782*	0	0	10
	0.72	1	0	0	0	0.70	0.988	1	1.000	1	1	0
	0.95	1	0	0	0	6.49	*3.841*	218	*3.149*	0	0	70
neos-555298	58.31	1100	1	1	12	53.14	**0.913**	655	**0.629**	1	1	9
	56.61	1014	1	1	15	51.74	**0.915**	685	**0.705**	1	1	2
	45.83	582	0	0	18	38.27	**0.839**	299	**0.585**	1	1	6
	56.29	1091	0	0	46	60.88	*1.080*	638	**0.620**	1	1	14
neos-555343	262.55	13175	2	2	742	571.14	*2.171*	49279	*3.720*	1	1	1002
	limit	1098062	1	2	6168	3912.80	**0.544**	303934	**0.277**	1	1	2700
	1202.76	185371	1	3	4599	4367.25	*3.629*	450743	*2.431*	0	0	12
	1273.73	158908	0	2	969	892.88	**0.701**	121732	**0.766**	0	0	414
neos-555424	1948.51	433289	1	1	4953	1107.60	**0.569**	96804	**0.224**	1	1	1231
	384.78	52136	1	1	954	84.69	**0.222**	3738	**0.073**	1	1	12
	441.68	60699	0	1	1216	192.18	**0.436**	20100	**0.332**	1	1	5
	786.56	155876	1	2	4404	6470.56	*8.217*	929190	*5.958*	1	1	3309
neos-555694	8.26	21	0	0	0	3.29	**0.463**	2	**0.843**	1	1	41
	3.10	6	0	0	0	2.83	**0.934**	3	0.972	3	3	4
	3.37	6	0	0	0	3.88	*1.117*	6	1.000	1	1	4
	2.71	6	0	0	0	6.02	*1.892*	7	1.009	0	0	0
neos-555771	2.74	6	0	0	0	3.21	*1.126*	7	1.009	1	1	7
	7.89	41	0	0	0	3.02	**0.452**	3	**0.730**	3	3	5
	2.33	6	0	0	0	2.01	**0.904**	2	0.962	2	2	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	2.27	6	0	0	0	1.00	**0.612**	1	0.953	1	1	0
neos-555884	limit	891052	1	0	5943	limit	1.000	749187	**0.841**	0	0	5
	limit	959891	1	1	5257	limit	1.000	946451	0.986	0	0	33
	limit	1003392	1	1	4250	limit	1.000	975471	0.972	0	0	17
	limit	1002806	1	0	10409	limit	1.000	881964	**0.880**	0	0	6
neos-555927	limit	2283610	1	2	40248	limit	1.000	2192751	0.960	3	3	11636
	limit	2247509	2	2	43796	limit	1.000	2161933	0.962	0	0	44
	limit	2333014	4	1	17523	limit	1.000	2133964	**0.915**	7	7	12978
	limit	2353215	1	4	10848	limit	1.000	2264565	0.962	0	0	14
neos-565672	3159.29	34	0	0	0	3300.74	1.045	29	0.963	0	0	0
	4453.48	22	0	0	0	4075.05	**0.915**	6	**0.869**	0	0	0
	3625.84	10	0	0	0	3614.12	0.997	10	1.000	0	0	0
	4657.22	20	0	0	0	4558.32	0.979	20	1.000	0	0	0
neos-565815	9.61	1	0	0	0	9.64	1.003	1	1.000	0	0	0
	10.49	1	0	0	0	10.51	1.002	1	1.000	0	0	0
	7.63	1	0	0	0	7.56	0.992	1	1.000	0	0	0
	8.72	1	0	0	0	8.67	0.995	1	1.000	0	0	0
neos-570431	9.54	277	0	0	10	9.60	1.006	277	1.000	0	0	0
	10.59	375	0	0	0	10.65	1.005	375	1.000	0	0	0
	9.42	285	0	0	0	9.55	1.012	285	1.000	0	0	0
	10.28	285	0	0	0	10.45	1.015	285	1.000	0	0	0
neos-574665	limit	11823492	1	2	2707	limit	1.000	11731149	0.992	1	1	130
	limit	8377099	1	1	382	limit	1.000	7389802	**0.882**	2	2	382
	limit	7561523	1	1	353	limit	1.000	5149872	**0.681**	1	1	414
	limit	10813446	1	0	546	limit	1.000	12464902	*1.153*	1	1	255
neos-578379	169.36	1	0	0	0	168.82	0.997	1	1.000	0	0	0
	171.15	1	0	0	0	169.83	0.992	1	1.000	0	0	0
	181.80	3	0	0	0	181.49	0.998	3	1.000	0	0	0
	171.99	1	0	0	0	170.83	0.993	1	1.000	0	0	0
neos-582605	limit	1245501	0	3	474	limit	1.000	1242457	0.998	0	0	0
	limit	1158851	0	1	587	limit	1.000	1158255	0.999	0	0	0
	limit	1113610	0	1	383	limit	1.000	1107569	0.995	0	0	0
	limit	1128241	0	1	365	limit	1.000	1121335	0.994	0	0	0
neos-583731	8.18	29	0	0	0	8.25	1.008	29	1.000	0	0	0
	6.65	17	0	0	0	6.71	1.008	17	1.000	0	0	0
	11.43	42	0	0	0	11.51	1.006	42	1.000	0	0	0
	6.58	19	0	0	0	6.66	1.011	19	1.000	0	0	0
neos-584146	limit	2258506	0	6	929	limit	1.000	2252842	0.997	0	0	0
	limit	2639465	0	3	1363	limit	1.000	2633782	0.998	0	0	0
	limit	1659074	0	4	374	limit	1.000	1650980	0.995	0	0	0
	limit	2799776	0	4	991	limit	1.000	2802053	1.001	0	0	0
neos-584851	7.52	7	0	0	0	7.60	1.009	7	1.000	0	0	0
	16.99	70	0	0	0	17.17	1.010	70	1.000	0	0	0
	13.94	7	0	0	0	13.94	1.000	7	1.000	0	0	0
	14.00	28	0	0	0	14.00	1.000	28	1.000	0	0	0
neos-584866	limit	269215	0	1	232	limit	1.000	261916	0.973	0	0	0
	limit	260943	0	0	154	limit	1.000	254866	0.977	0	0	0
	limit	259269	1	0	87	limit	1.000	251324	0.969	0	0	0
	limit	281465	0	0	98	limit	1.000	276742	0.983	0	0	0
neos-585192	15.82	406	0	0	0	15.89	1.004	406	1.000	0	0	0
	19.92	676	0	0	0	20.00	1.004	676	1.000	0	0	0
	18.88	359	0	0	0	18.76	0.994	359	1.000	0	0	0
	19.78	606	0	0	0	19.87	1.004	606	1.000	0	0	0
neos-585467	10.23	91	0	0	0	10.22	0.999	91	1.000	0	0	0
	9.21	93	0	0	0	9.26	1.005	93	1.000	0	0	0
	6.70	39	0	0	0	6.72	1.003	39	1.000	0	0	0
	8.84	89	0	0	0	8.84	1.000	89	1.000	0	0	0
neos-593853	199.18	114959	2	2	868	108.07	**0.545**	57342	**0.499**	0	0	0
	138.41	63753	1	1	264	139.92	1.011	63753	1.000	0	0	0
	106.47	59663	0	0	508	100.35	**0.943**	53947	**0.904**	0	0	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	89.91	42458	0	0	289	90.09	1.002	42458	1.000	0	0	0
neos-595904	10.66	3	0	0	0	10.94	1.024	3	1.000	0	0	64
	18.65	4	0	0	0	20.97	*1.118*	3	0.990	0	0	150
	16.38	4	0	0	0	13.73	**0.848**	4	1.000	0	0	548
	19.97	5	0	0	0	24.22	*1.203*	6	1.010	0	0	119
neos-595905	1.57	2	0	0	0	1.57	1.000	2	1.000	0	0	2
	1.92	3	0	0	0	2.30	*1.130*	2	0.990	0	0	53
	1.34	2	0	0	0	1.39	1.021	2	1.000	1	1	89
	1.48	2	0	0	0	1.34	**0.944**	2	1.000	0	0	52
neos-595925	9.78	465	0	0	0	11.52	*1.161*	7	**0.189**	0	0	130
	20.69	1856	0	0	15	16.49	**0.806**	15	**0.059**	0	0	18
	10.05	262	0	0	0	14.24	*1.379*	600	*1.934*	0	0	31
	14.82	363	0	0	0	10.13	**0.704**	3	**0.222**	0	0	136
neos-598183	4.65	4	0	0	0	8.08	*1.607*	6	1.019	0	0	29
	6.41	6	0	0	0	3.99	**0.673**	4	0.981	0	0	31
	5.95	11	0	0	0	6.05	1.014	18	*1.063*	0	0	53
	5.50	7	0	0	0	7.51	*1.309*	6	0.991	0	0	12
neos-603073	146.92	37727	1	1	93	57.64	**0.396**	6238	**0.168**	1	1	150
	237.52	46627	0	1	54	316.73	*1.332*	86267	*1.848*	0	0	0
	6383.98	2173680	0	0	64	34.69	**0.006**	3876	**0.002**	1	1	0
	171.47	32941	0	0	36	201.97	*1.177*	35671	*1.083*	1	1	77
neos-611135	limit	253233	1	1	1461	limit	1.000	188860	**0.746**	0	0	0
	limit	197053	0	1	691	limit	1.000	181217	**0.920**	0	0	0
	limit	184863	1	1	448	limit	1.000	178456	0.965	0	0	0
	limit	166771	1	1	698	limit	1.000	224658	*1.347*	0	0	0
neos-611838	26.61	282	2	1	1	28.00	*1.050*	292	1.026	16	2	0
	29.33	319	0	0	0	28.23	0.964	226	**0.778**	15	0	0
	25.72	272	2	2	0	25.04	0.975	197	**0.798**	14	0	0
	28.96	210	1	0	0	28.85	0.996	204	0.981	11	0	0
neos-612125	19.94	45	1	0	0	19.65	0.986	76	*1.214*	8	0	0
	23.16	154	0	0	0	20.96	**0.909**	62	**0.638**	10	0	0
	24.09	175	0	0	0	19.53	**0.818**	38	**0.502**	8	0	0
	21.59	161	0	0	0	26.58	*1.221*	23	**0.471**	21	0	0
neos-612143	27.24	203	0	0	0	26.58	0.977	216	1.043	13	0	0
	24.71	177	1	0	0	23.09	**0.937**	116	**0.780**	13	0	0
	32.28	170	1	1	0	28.07	**0.873**	138	**0.881**	16	0	0
	29.60	302	0	0	0	26.88	**0.911**	242	**0.851**	12	0	0
neos-612162	25.00	197	0	0	0	23.93	0.959	173	**0.919**	3	0	0
	27.35	184	0	0	0	26.99	0.987	181	0.989	6	0	0
	21.42	219	1	0	0	21.04	0.983	189	**0.906**	5	0	0
	25.63	265	0	0	0	24.73	0.966	224	**0.888**	10	0	0
neos-619167	limit	178	0	0	9	limit	1.000	176	0.993	0	0	0
	limit	150	0	0	0	limit	1.000	147	0.988	0	0	0
	limit	136	0	0	3	limit	1.000	135	0.996	0	0	0
	limit	119	0	0	0	limit	1.000	118	0.995	0	0	0
neos-631164	limit	498004	1	4	96	limit	1.000	598636	*1.202*	0	0	0
	limit	261457	1	1	30	limit	1.000	274794	*1.051*	0	0	0
	limit	530556	3	3	275	limit	1.000	601177	*1.133*	0	0	0
	limit	387495	4	4	342	limit	1.000	560465	*1.446*	0	0	0
neos-631517	limit	481865	8	8	248	limit	1.000	482368	1.001	0	0	0
	limit	523823	5	5	305	limit	1.000	525599	1.003	0	0	0
	limit	803671	0	0	78	limit	1.000	441042	**0.549**	0	0	0
	limit	605015	0	0	13	limit	1.000	387263	**0.640**	0	0	0
neos-631694	limit	930570	1	1	7561	limit	1.000	915420	0.984	0	0	0
	limit	625246	0	0	4827	limit	1.000	619951	0.992	0	0	0
	233.92	8911	0	0	1159	235.31	1.006	8911	1.000	0	0	0
	limit	1069187	1	1	5481	limit	1.000	1054870	0.987	0	0	0
neos-631709	limit	5454	1	1	376	limit	1.000	5464	1.002	0	0	0
	limit	681	0	0	124	limit	1.000	662	0.976	0	0	0
	limit	371	1	1	189	limit	1.000	352	0.960	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	186	1	1	361	limit	1.000	180	0.979	0	0	0
neos-631710	limit	1	0	0	0	limit	1.000	1	1.000	0	0	0
	limit	6	0	0	0	limit	1.000	6	1.000	0	0	0
	limit	1	0	0	0	limit	1.000	1	1.000	0	0	0
	limit	3	0	0	0	limit	1.000	3	1.000	0	0	0
neos-631784	5956.65	172202	1	1	6558	5969.52	1.002	172202	1.000	0	0	0
	2235.56	82947	0	0	3427	2236.67	1.000	82947	1.000	0	0	0
	limit	386029	1	1	18888	limit	1.000	383005	0.992	0	0	0
	3942.96	159799	1	1	7455	3963.70	1.005	159799	1.000	0	0	0
neos-632335	10.03	193	0	0	0	9.91	0.989	193	1.000	0	0	0
	9.98	193	0	0	0	9.96	0.998	193	1.000	0	0	0
	10.08	193	0	0	0	9.98	0.991	193	1.000	0	0	0
	10.19	197	0	0	0	10.12	0.994	197	1.000	0	0	0
neos-633273	10.59	259	0	0	0	10.50	0.992	259	1.000	0	0	0
	10.52	259	0	0	0	10.34	0.984	259	1.000	0	0	0
	10.18	253	0	0	0	10.15	0.997	253	1.000	0	0	0
	10.43	259	0	0	0	10.38	0.996	259	1.000	0	0	0
neos-655508	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-662469	limit	31575	1	1	747	limit	1.000	68330	*2.160*	0	0	118
	limit	47257	1	1	817	limit	1.000	61845	*1.308*	1	1	2534
	limit	79015	1	1	1095	6607.85	**0.918**	54861	**0.695**	1	1	2064
	limit	28051	2	2	1533	limit	1.000	67661	*2.407*	0	0	718
neos-686190	92.14	5703	0	0	660	91.42	0.992	6343	*1.110*	0	0	49
	150.88	13529	0	0	216	98.56	**0.656**	7722	**0.574**	0	0	17
	118.17	8992	0	0	608	87.60	**0.743**	5811	**0.650**	0	0	18
	244.44	21982	1	1	3906	84.81	**0.350**	5618	**0.259**	0	0	44
neos-691058	limit	6531	1	1	275	limit	1.000	5408	**0.831**	0	0	0
	limit	7716	0	7	86	limit	1.000	5607	**0.730**	0	0	0
	limit	12630	1	2	566	limit	1.000	31626	*2.492*	0	0	0
	limit	5974	1	3	321	limit	1.000	26296	*4.346*	0	0	0
neos-691073	limit	24323	0	7	94	limit	1.000	14046	**0.579**	0	0	0
	limit	15605	1	5	117	limit	1.000	33561	*2.143*	0	0	50
	limit	11415	0	3	62	limit	1.000	14850	*1.298*	0	0	0
	limit	11624	1	3	108	limit	1.000	12367	*1.063*	1	1	16
neos-693347	1408.75	12433	0	0	3549	3986.35	*2.828*	16773	*1.346*	0	0	0
	1923.24	17666	0	1	4621	3410.62	*1.773*	47415	*2.674*	0	0	0
	5730.59	74565	0	0	1716	4874.22	**0.851**	34373	**0.462**	0	0	0
	3504.75	46192	2	0	1238	3149.94	**0.899**	34026	**0.737**	0	0	0
neos-702280	limit	6664	0	0	3	limit	1.000	6769	1.016	0	0	0
	limit	6471	0	0	6	limit	1.000	6437	0.995	0	0	0
	limit	6649	0	0	3	limit	1.000	6673	1.004	0	0	0
	limit	7040	0	0	11	limit	1.000	7077	1.005	0	0	0
neos-709469	0.50	13	0	0	0	0.50	1.000	13	1.000	0	0	0
	0.64	377	0	0	35	0.65	1.006	377	1.000	0	0	0
	0.50	120	0	0	0	0.50	1.000	120	1.000	0	0	0
	0.55	315	0	0	3	0.59	1.026	315	1.000	0	0	0
neos-717614	21.08	7251	0	0	4	66.41	*3.053*	54649	*7.448*	0	0	79
	35.62	19659	0	1	5	111.36	*3.068*	68576	*3.476*	0	0	49
	3484.43	1782616	0	0	24	14.77	**0.005**	2829	**0.002**	0	0	51
	46.73	38062	0	3	16	11.16	**0.255**	1421	**0.040**	0	0	61
neos-738098	limit	607	0	0	306	limit	1.000	2124	*3.146*	0	0	1025
	limit	440	0	0	226	limit	1.000	663	*1.413*	0	0	0
	limit	511	0	0	556	limit	1.000	2209	*3.779*	0	0	410
	limit	816	0	0	717	limit	1.000	2026	*2.321*	0	0	0
neos-775946	7.03	4	0	0	0	7.09	1.007	3	0.990	3	3	0
	12.44	44	0	0	0	12.34	0.993	40	0.972	0	0	0
	9.01	3	0	0	0	8.24	**0.923**	3	1.000	3	3	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	7.08	4	0	0	0	7.58	*1.062*	5	1.010	1	1	5
neos-780889	284.39	2	0	0	0	169.55	**0.598**	1	0.990	1	1	0
	53.64	1	0	0	0	53.93	1.005	1	1.000	0	0	0
	45.83	1	0	0	0	46.67	1.018	1	1.000	0	0	0
	46.41	1	0	0	0	46.93	1.011	1	1.000	0	0	0
neos-785899	2.13	22	0	0	0	2.15	1.006	24	1.016	0	0	19
	4.23	35	0	0	0	2.82	**0.730**	36	1.007	0	0	60
	3.58	39	0	0	0	4.14	*1.122*	78	*1.281*	0	0	92
	2.66	37	0	0	0	3.53	*1.238*	27	**0.927**	0	0	30
neos-785912	41.76	384	0	0	0	41.70	0.999	384	1.000	0	0	0
	34.78	227	0	0	0	34.69	0.997	227	1.000	0	0	0
	36.20	331	0	0	0	35.83	0.990	331	1.000	0	0	0
	82.41	290	0	0	11	79.55	0.966	290	1.000	0	0	0
neos-785914	8.56	16	0	0	0	8.54	0.998	16	1.000	0	0	0
	8.55	14	0	0	0	8.56	1.001	14	1.000	0	0	0
	4.73	16	0	0	0	4.72	0.998	16	1.000	0	0	0
	5.37	18	0	0	0	5.28	0.986	18	1.000	0	0	0
neos-787933	1.40	1	0	0	0	1.41	1.004	1	1.000	0	0	0
	1.36	1	0	0	0	1.40	1.017	1	1.000	0	0	0
	1.42	1	0	0	0	1.41	0.996	1	1.000	0	0	0
	1.44	1	0	0	0	1.41	0.988	1	1.000	0	0	0
neos-791021	424.68	89	0	0	18	428.22	1.008	89	1.000	0	0	0
	391.56	91	1	1	9	393.65	1.005	91	1.000	0	0	0
	296.35	47	1	2	7	296.68	1.001	47	1.000	0	0	0
	431.62	81	1	2	17	434.84	1.007	81	1.000	0	0	0
neos-796608	185.19	864703	0	0	40	0.50	**0.008**	2	**0.000**	1	1	5
	183.39	843360	0	0	37	0.50	**0.008**	2	**0.000**	1	1	0
	0.50	2	0	0	0	0.50	1.000	3	1.010	1	1	3
	181.16	848510	0	0	154	0.50	**0.008**	2	**0.000**	1	1	0
neos-799838	33.15	1	0	0	0	33.21	1.002	1	1.000	1	1	0
	26.14	1	0	0	0	26.21	1.003	1	1.000	0	0	0
	98.09	10	0	0	0	143.95	*1.463*	25	*1.136*	0	0	0
	26.74	1	0	0	0	26.77	1.001	1	1.000	0	0	0
neos-801834	41.04	159	0	0	0	39.39	0.961	109	**0.807**	0	0	0
	39.50	175	0	0	0	39.04	0.989	191	*1.058*	0	0	0
	46.38	217	0	0	0	37.11	**0.804**	133	**0.735**	0	0	0
	35.63	155	0	0	0	44.96	*1.255*	189	*1.133*	0	0	0
neos-803219	37.61	14134	3	3	876	38.49	1.023	13185	**0.933**	0	0	16
	30.59	10451	1	1	517	39.65	*1.287*	14373	*1.372*	0	0	10
	26.99	11087	0	0	279	25.23	**0.937**	7831	**0.709**	0	0	15
	27.03	9225	2	1	649	39.48	*1.444*	14551	*1.571*	0	0	9
neos-803220	80.27	46306	2	2	1404	76.96	0.959	43393	**0.937**	0	0	0
	72.80	41753	2	2	1251	68.36	**0.940**	41242	0.988	0	0	0
	64.67	38753	2	2	1137	72.56	*1.120*	41998	*1.084*	0	0	3
	77.08	43474	3	3	1135	70.28	**0.913**	40378	**0.929**	0	0	5
neos-806323	30.86	5789	1	1	588	29.50	0.957	6299	*1.087*	0	0	27
	41.17	9542	0	1	428	36.67	**0.893**	8845	**0.928**	0	0	22
	35.32	7845	1	0	534	28.28	**0.806**	4921	**0.632**	0	0	11
	33.55	7734	1	1	415	25.11	**0.756**	5457	**0.709**	0	0	27
neos-807454	2.12	1	0	0	0	2.12	1.000	1	1.000	0	0	0
	2.25	1	0	0	0	2.26	1.003	1	1.000	0	0	0
	2.17	1	0	0	0	2.19	1.006	1	1.000	0	0	0
	1.86	1	0	0	0	1.82	0.986	1	1.000	0	0	0
neos-807639	16.47	2824	1	1	399	15.14	**0.924**	2641	**0.937**	0	0	16
	16.15	2595	0	0	365	17.09	*1.055*	2767	*1.064*	1	1	315
	15.63	2501	0	0	307	16.45	1.049	2393	0.958	1	1	385
	17.39	2933	0	0	352	16.72	0.964	2634	**0.901**	0	0	17
neos-807705	26.69	3259	1	1	242	27.95	1.046	3928	*1.199*	2	2	474
	35.28	4408	2	2	325	28.83	**0.822**	3816	**0.869**	0	0	14
	26.27	3762	2	2	284	28.09	*1.067*	3967	*1.053*	2	2	287

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	27.09	3708	2	2	366	26.36	0.974	2998	**0.814**	1	1	313
neos-808072	25.96	411	0	0	32	20.46	**0.796**	172	**0.532**	0	0	0
	27.34	235	0	0	98	18.98	**0.705**	121	**0.660**	0	0	0
	16.06	59	0	0	0	17.63	*1.092*	40	**0.881**	1	1	0
	19.50	176	0	0	0	18.36	**0.944**	91	**0.692**	0	0	0
neos-808214	22.56	902	1	0	406	22.60	1.002	902	1.000	0	0	0
	17.29	836	0	0	142	17.31	1.001	836	1.000	0	0	0
	16.25	581	0	0	97	16.28	1.002	581	1.000	0	0	0
	22.00	1488	0	0	553	21.90	0.996	1488	1.000	0	0	0
neos-810286	19.55	5	0	0	0	196.94	*9.632*	786	*8.438*	0	0	0
	221.69	474	0	0	294	21.33	**0.100**	5	**0.183**	0	0	0
	299.64	781	0	0	263	26.21	**0.091**	5	**0.119**	0	0	0
	241.94	1026	1	1	851	86.64	**0.361**	382	**0.428**	0	0	0
neos-810326	50.31	1196	0	0	275	26.89	**0.544**	527	**0.484**	1	1	0
	15.01	177	0	0	0	49.06	*3.127*	1095	*4.314*	1	1	88
	35.82	851	0	0	372	88.79	*2.439*	1956	*2.162*	2	2	63
	37.72	882	0	0	260	42.71	*1.129*	1006	*1.126*	0	0	289
neos-820146	limit	1746008	0	0	35128	limit	1.000	1744001	0.999	0	0	0
	limit	1174341	0	0	23819	limit	1.000	1157911	0.986	0	0	0
	limit	2932659	0	0	44210	limit	1.000	2901839	0.989	0	0	0
	limit	2047225	0	0	69619	limit	1.000	2057438	1.005	0	0	0
neos-820157	limit	1615861	0	0	49357	limit	1.000	1607753	0.995	0	0	0
	limit	1757370	0	0	62927	limit	1.000	1759465	1.001	0	0	0
	limit	1337318	0	0	42159	limit	1.000	1320091	0.987	0	0	0
	limit	2137034	0	0	61853	limit	1.000	2125168	0.994	0	0	0
neos-820879	49.70	31	0	0	0	43.67	**0.881**	376	*3.634*	0	0	0
	52.16	411	0	0	0	59.04	*1.129*	318	**0.818**	0	0	0
	42.96	32	0	0	0	34.36	**0.804**	15	**0.871**	0	0	0
	57.52	205	0	0	0	43.65	**0.763**	23	**0.403**	0	0	0
neos-824661	1080.45	46	1	1	9	1086.36	1.005	46	1.000	0	0	0
	824.67	37	1	1	16	834.60	1.012	37	1.000	0	0	0
	992.14	85	1	1	3	1003.22	1.011	85	1.000	0	0	0
	1527.24	43	0	0	3	1575.15	1.031	51	*1.056*	0	0	0
neos-824695	517.05	67	0	1	54	524.58	1.015	67	1.000	0	0	0
	286.27	31	1	0	36	292.43	1.021	31	1.000	0	0	0
	412.60	37	1	1	67	418.41	1.014	37	1.000	0	0	0
	256.97	19	1	1	0	260.52	1.014	19	1.000	0	0	0
neos-825075	1.12	1	0	0	0	1.16	1.019	1	1.000	1	1	0
	1.81	7	0	0	0	2.07	*1.093*	11	1.037	1	1	0
	1.77	5	0	0	0	2.31	*1.195*	2	0.971	2	2	2
	2.02	6	0	0	0	1.69	**0.891**	2	0.962	1	1	0
neos-826224	69.42	1	0	0	0	70.21	1.011	1	1.000	0	0	0
	236.72	45	1	1	0	237.48	1.003	45	1.000	0	0	0
	15.31	1	0	0	0	15.72	1.025	1	1.000	0	0	0
	10.50	1	0	0	0	10.67	1.015	1	1.000	0	0	0
neos-826250	172.64	18	1	1	0	173.65	1.006	18	1.000	0	0	0
	215.61	24	1	1	0	216.83	1.006	24	1.000	0	0	0
	40.46	1	0	0	0	40.86	1.010	1	1.000	0	0	0
	180.55	41	0	0	0	181.44	1.005	41	1.000	0	0	0
neos-826650	limit	37527	0	0	632	limit	1.000	37072	0.988	0	0	0
	limit	53858	0	0	1602	limit	1.000	53081	0.986	0	0	0
	limit	16051	0	1	933	limit	1.000	15926	0.992	0	0	0
	limit	54918	0	1	2107	limit	1.000	54538	0.993	0	0	0
neos-826694	222.36	24	0	0	0	223.78	1.006	24	1.000	0	0	0
	403.32	57	1	1	2	406.46	1.008	57	1.000	0	0	0
	435.49	201	0	0	0	436.82	1.003	201	1.000	0	0	0
	265.10	71	1	1	0	265.76	1.002	71	1.000	0	0	0
neos-826812	26.07	1	0	0	0	26.30	1.008	1	1.000	0	0	0
	199.86	18	1	1	0	45.24	**0.230**	1	**0.856**	0	0	0
	126.48	5	0	0	0	127.26	1.006	5	1.000	0	0	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	204.42	7	0	0	0	206.85	1.012	7	1.000	0	0	0
neos-826841	limit	220633	0	0	1609	limit	1.000	137052	**0.621**	0	0	0
	limit	131119	0	0	1443	limit	1.000	299725	*2.285*	0	0	0
	limit	156266	3	3	1364	limit	1.000	146332	**0.936**	0	0	0
	limit	135271	0	0	1629	limit	1.000	206931	*1.529*	0	0	0
neos-827015	1222.14	337	0	0	441	877.19	**0.718**	188	**0.659**	0	0	0
	1197.58	301	0	0	136	1217.53	1.017	221	**0.800**	0	0	0
	3131.30	924	1	1	423	1215.96	**0.389**	300	**0.391**	0	0	0
	696.41	174	0	0	358	1014.65	*1.456*	230	*1.204*	0	0	0
neos-827175	6.13	1	0	0	0	6.29	1.022	1	1.000	0	0	0
	8.04	1	0	0	0	8.36	1.035	1	1.000	0	0	0
	6.73	1	0	0	0	6.92	1.025	1	1.000	0	0	0
	32.45	1	0	0	0	32.73	1.008	1	1.000	0	0	0
neos-829552	254.13	179	0	0	27	696.45	*2.734*	689	*2.828*	0	0	0
	263.64	249	0	0	188	307.58	*1.166*	202	**0.865**	0	0	0
	266.01	230	0	0	69	341.57	*1.283*	353	*1.373*	0	0	0
	379.52	419	0	0	146	390.22	1.028	330	**0.829**	0	0	0
neos-830439	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-831188	248.33	2585	0	0	298	289.03	*1.163*	2522	0.977	0	0	0
	275.04	2749	0	0	528	261.06	**0.949**	2490	**0.909**	0	0	0
	318.83	3119	0	0	280	205.14	**0.645**	1910	**0.624**	0	0	0
	302.70	2773	0	1	595	230.46	**0.762**	2162	**0.787**	0	0	0
neos-839838	1567.38	55355	1	1	70	1912.03	*1.220*	64421	*1.163*	0	0	0
	985.06	35500	0	0	10	1067.49	*1.084*	32201	**0.907**	0	0	0
	1402.07	45773	1	1	33	1386.17	0.989	45672	0.998	0	0	0
	764.93	26284	2	2	142	752.32	0.984	27539	1.048	0	0	0
neos-839859	38.77	1834	0	0	0	35.98	**0.930**	2131	*1.154*	0	0	25
	42.85	2550	0	0	15	64.96	*1.504*	5244	*2.017*	0	0	25
	45.08	2538	0	0	4	50.17	*1.110*	2761	*1.085*	0	0	0
	64.95	4753	0	0	29	53.72	**0.830**	3434	**0.728**	0	0	25
neos-839894	limit	198	0	0	16	limit	1.000	1229	*4.460*	2	2	33
	limit	178	0	0	0	limit	1.000	316	*1.496*	0	0	0
	limit	171	0	0	0	limit	1.000	170	0.996	0	0	0
	limit	278	0	0	0	limit	1.000	42	**0.376**	0	0	0
neos-841664	limit	89850	25	11	2341	limit	1.000	20588	**0.230**	502	45	8655
	limit	139541	19	18	291	limit	1.000	43991	**0.316**	323	47	6538
	2990.72	45747	75	8	1339	limit	*2.407*	76827	*1.678*	448	74	9266
	limit	76369	22	8	981	limit	1.000	121197	*1.586*	512	56	6807
neos-847051	limit	2513037	2	6	1	limit	1.000	2503522	0.996	0	0	0
	limit	2723021	0	3	135	limit	1.000	2712222	0.996	0	0	0
	limit	1023008	1	2	126	limit	1.000	1022801	1.000	0	0	0
	limit	3248415	3	4	8	limit	1.000	3245004	0.999	0	0	0
neos-847302	limit	310497	1	1	305	limit	1.000	310496	1.000	0	0	0
	limit	285614	0	0	359	limit	1.000	285607	1.000	0	0	0
	limit	272874	1	1	841	limit	1.000	272101	0.997	0	0	0
	limit	369028	2	1	815	limit	1.000	369408	1.001	0	0	0
neos-848150	11.36	23	0	0	3	11.39	1.002	23	1.000	0	0	0
	12.11	22	0	0	0	12.10	0.999	22	1.000	0	0	0
	1.07	1	0	0	0	1.09	1.010	1	1.000	0	0	0
	13.35	30	0	0	0	13.35	1.000	30	1.000	0	0	0
neos-848198	limit	1461	79	82	17	limit	1.000	938	**0.665**	135	0	119
	limit	1387	185	11	21	limit	1.000	614	**0.480**	112	0	109
	limit	3662	194	11	34	limit	1.000	948	**0.279**	14	0	73
	limit	4005	143	14	25	limit	1.000	1309	**0.343**	49	0	57
neos-848589	2427.32	117	0	0	0	2456.98	1.012	117	1.000	0	0	0
	1890.58	45	0	0	0	1916.19	1.014	45	1.000	0	0	0
	1141.60	23	0	0	0	1146.16	1.004	23	1.000	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	1104.10	49	0	0	0	1133.88	1.027	49	1.000	0	0	0
neos-848845	890.66	54283	0	0	464	892.11	1.002	54283	1.000	0	0	0
	498.02	29867	0	0	521	497.54	0.999	29867	1.000	0	0	0
	135.69	2323	0	0	91	136.10	1.003	2323	1.000	0	0	0
	175.49	3297	0	0	186	176.46	1.005	3297	1.000	0	0	0
neos-849702	242.40	12631	0	0	295	243.29	1.004	12631	1.000	0	0	0
	101.34	3749	0	0	194	101.12	0.998	3749	1.000	0	0	0
	2438.94	192391	0	0	649	2435.60	0.999	192391	1.000	0	0	0
	82.80	1786	0	0	121	82.50	0.996	1786	1.000	0	0	0
neos-850681	6.34	6	0	0	0	2.74	**0.510**	1	0.953	1	1	0
	6.52	6	0	0	0	7.25	*1.097*	2	0.962	2	2	0
	5.38	6	0	0	0	2.87	**0.607**	1	0.953	1	1	0
	9.33	7	0	0	0	2.53	**0.342**	1	**0.944**	1	1	0
neos-856059	4976.28	314313	0	0	1229	4979.48	1.001	314313	1.000	0	0	0
	4073.48	259764	2	0	1919	4085.75	1.003	259764	1.000	0	0	0
	3996.11	250654	2	1	1461	4006.26	1.003	250654	1.000	0	0	0
	4700.47	285239	2	0	701	4623.19	0.984	285239	1.000	0	0	0
neos-859770	128.26	1	0	0	0	128.93	1.005	1	1.000	0	0	0
	143.67	1	0	0	0	143.72	1.000	1	1.000	0	0	0
	126.17	1	0	0	0	126.93	1.006	1	1.000	0	0	0
	134.49	1	0	0	0	133.40	0.992	1	1.000	0	0	0
neos-860244	4.52	1	0	0	0	4.58	1.011	1	1.000	1	1	0
	4.90	1	0	0	0	4.95	1.008	1	1.000	1	1	0
	5.14	1	0	0	0	5.12	0.997	1	1.000	1	1	0
	3.97	1	0	0	0	3.99	1.004	1	1.000	1	1	0
neos-860300	16.83	2	0	0	0	19.23	*1.135*	3	1.010	0	0	0
	15.23	2	0	0	0	19.11	*1.239*	2	1.000	1	1	0
	18.03	3	0	0	0	19.25	*1.064*	3	1.000	1	1	7
	15.68	2	0	0	0	20.44	*1.285*	3	1.010	0	0	0
neos-862348	14.08	166	0	0	0	11.50	**0.829**	129	**0.861**	0	0	4
	7.30	38	0	0	0	9.80	*1.301*	54	*1.116*	0	0	7
	16.37	209	0	0	0	18.14	*1.102*	324	*1.372*	1	1	0
	12.01	4	0	0	0	12.58	1.044	4	1.000	1	1	64
neos-863472	48.06	42426	0	0	598	53.57	*1.112*	46819	*1.103*	1	1	116
	52.35	48044	0	0	672	39.79	**0.765**	37742	**0.786**	0	0	0
	36.79	30659	0	0	395	57.59	*1.550*	54245	*1.767*	0	0	12
	47.30	44326	0	0	644	47.65	1.007	40230	**0.908**	0	0	6
neos-872648	limit	16	0	0	0	limit	1.000	16	1.000	5	0	0
	limit	238	0	0	2	limit	1.000	376	*1.408*	0	0	0
	limit	51	0	0	2	limit	1.000	35	**0.894**	8	0	0
	limit	228	0	0	0	limit	1.000	288	*1.183*	0	0	0
neos-873061	limit	2058	3	0	2	limit	1.000	1551	**0.765**	41	0	4
	limit	11901	28	0	8	limit	1.000	10750	**0.904**	119	0	55
	limit	2057	30	0	6	limit	1.000	1518	**0.750**	0	0	0
	limit	11011	1	0	0	limit	1.000	305	**0.036**	0	0	0
neos-876808	limit	28	0	0	0	limit	1.000	31	1.023	0	0	0
	limit	23	0	0	0	limit	1.000	9	**0.886**	0	0	0
	limit	6	0	0	0	limit	1.000	5	0.991	0	0	0
	limit	1	0	0	0	limit	1.000	1	1.000	0	0	0
neos-880324	0.79	12	0	0	0	0.78	0.994	12	1.000	0	0	0
	1.03	8	0	0	0	1.03	1.000	8	1.000	0	0	0
	0.63	4	0	0	0	0.63	1.000	4	1.000	0	0	0
	0.95	19	0	0	0	0.95	1.000	19	1.000	0	0	0
neos-881765	3.25	54	0	0	0	3.32	1.016	54	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	2.25	22	0	0	0	2.21	0.988	22	1.000	0	0	0
	2.34	23	0	0	0	2.31	0.991	23	1.000	0	0	0
neos-885086	1498.15	236	0	0	0	1523.27	1.017	236	1.000	0	0	0
	limit	1116	0	0	133	limit	1.000	1097	0.984	0	0	0
	limit	918	0	0	0	limit	1.000	915	0.997	0	0	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	3112.19	272	0	0	0	3139.86	1.009	272	1.000	0	0	0
neos-885524	68.13	401	0	0	12	2567.35	*37.152*	4264	*8.711*	0	0	0
	18.59	25	0	0	0	650.47	*33.255*	653	*6.024*	0	0	0
	limit	13927	0	0	23	860.25	**0.120**	1302	**0.100**	0	0	0
	limit	14231	0	0	46	4744.09	**0.659**	4109	**0.294**	0	0	0
neos-886822	2602.08	211217	0	0	888	2606.75	1.002	211217	1.000	0	0	0
	1588.83	150024	0	0	553	1601.90	1.008	150024	1.000	0	0	0
	2630.78	197060	0	0	1054	2654.23	1.009	197060	1.000	0	0	0
	2420.72	235585	0	0	679	2425.59	1.002	235585	1.000	0	0	0
neos-892255	73.05	751	0	0	2	73.49	1.006	751	1.000	0	0	0
	92.18	487	0	0	5	92.54	1.004	487	1.000	0	0	0
	77.54	298	0	0	10	77.76	1.003	298	1.000	0	0	0
	40.97	290	0	0	0	41.09	1.003	290	1.000	0	0	0
neos-905856	18.38	375	0	0	237	18.31	0.996	375	1.000	0	0	0
	95.57	7861	0	0	360	95.61	1.000	7861	1.000	0	0	0
	127.36	9876	0	0	226	127.29	0.999	9876	1.000	0	0	0
	568.82	52807	0	0	567	570.80	1.003	52807	1.000	0	0	0
neos-906865	102.02	17218	0	0	77	102.44	1.004	17218	1.000	0	0	0
	133.25	24206	0	0	113	133.51	1.002	24206	1.000	0	0	0
	134.89	27518	0	0	111	135.30	1.003	27518	1.000	0	0	0
	108.76	22634	0	0	189	109.27	1.005	22634	1.000	0	0	0
neos-911880	318.80	166853	3	3	269	317.76	0.997	166853	1.000	0	0	0
	limit	5782937	0	2	1084	limit	1.000	7416819	*1.283*	0	0	0
	limit	1653013	0	3	219	3437.65	**0.478**	2846458	*1.722*	0	0	0
	limit	7616696	1	2	1696	901.52	**0.125**	706391	**0.093**	0	0	0
neos-911970	limit	6033380	1	6	2011	limit	1.000	7665683	*1.271*	0	0	0
	limit	6863340	0	4	1821	limit	1.000	6300371	**0.918**	0	0	0
	limit	6016562	0	6	1361	limit	1.000	4448238	**0.739**	0	0	0
	275.56	111525	1	5	77	limit	*26.038*	6712738	*60.137*	0	0	0
neos-912015	7.51	28	0	0	0	11.40	*1.457*	264	*2.844*	0	0	0
	4.64	21	0	0	0	7.07	*1.431*	18	0.975	0	0	60
	13.80	567	0	0	125	11.74	**0.861**	286	**0.579**	0	0	12
	7.21	29	0	0	0	8.68	*1.179*	43	*1.109*	0	0	15
neos-912023	8.04	20	0	0	0	4.72	**0.633**	5	**0.875**	0	0	18
	4.65	5	0	0	0	4.77	1.021	5	1.000	0	0	21
	6.21	22	0	0	0	7.87	*1.230*	41	*1.156*	0	0	18
	8.81	99	0	0	0	8.26	**0.944**	68	**0.844**	0	0	10
neos-913984	2.56	1	0	0	0	2.56	1.000	1	1.000	0	0	0
	2.55	1	0	0	0	2.53	0.994	1	1.000	0	0	0
	2.58	1	0	0	0	2.52	0.983	1	1.000	0	0	0
	2.57	1	0	0	0	2.51	0.983	1	1.000	0	0	0
neos-914441	7.10	1	0	0	0	7.03	0.991	1	1.000	0	0	0
	3.54	1	0	0	0	3.50	0.991	1	1.000	0	0	0
	13.51	2	0	0	0	13.47	0.997	2	1.000	0	0	0
	8.16	2	0	0	0	8.18	1.002	2	1.000	0	0	0
neos-916173	80.17	10649	0	0	32	79.56	0.992	10649	1.000	0	0	0
	66.02	7774	0	0	29	65.98	0.999	7774	1.000	0	0	0
	116.49	12392	0	0	63	115.68	0.993	12392	1.000	0	0	0
	78.65	8603	0	0	95	77.80	0.989	8603	1.000	0	0	0
neos-916792	1060.58	138606	2	2	150	1062.32	1.002	138606	1.000	0	0	0
	1129.93	161126	1	1	394	1130.58	1.001	161126	1.000	0	0	0
	738.07	87110	0	2	199	739.20	1.002	87110	1.000	0	0	0
	1486.10	230216	2	2	237	1479.23	0.995	230216	1.000	0	0	0
neos-930752	limit	2814	0	3	116	limit	1.000	2216	**0.795**	0	0	0
	limit	2904	0	5	95	limit	1.000	2872	0.989	0	0	0
	limit	2945	1	3	1068	limit	1.000	3132	*1.061*	0	0	0
	limit	3104	0	4	319	limit	1.000	3072	0.990	0	0	0
neos-931517	limit	1744	2	2	466	limit	1.000	1794	1.027	0	0	0
	limit	1962	1	1	449	limit	1.000	1399	**0.727**	0	0	0
	limit	1280	1	1	0	limit	1.000	1400	*1.087*	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	1570	3	3	1135	limit	1.000	2589	*1.610*	0	0	0
neos-931538	60.56	5	0	0	0	68.14	*1.123*	5	1.000	0	0	0
	75.72	5	0	0	0	87.57	*1.154*	5	1.000	0	0	0
	83.03	5	0	0	0	87.45	*1.053*	5	1.000	0	0	0
	81.81	5	0	0	0	85.35	1.043	5	1.000	0	0	0
neos-932721	2.66	1	0	0	0	4.89	*1.609*	1	1.000	0	0	0
	2.25	1	0	0	0	4.07	*1.560*	1	1.000	0	0	0
	2.25	1	0	0	0	3.96	*1.526*	1	1.000	0	0	0
	1.97	1	0	0	0	4.96	*2.007*	1	1.000	0	0	0
neos-932816	limit	1459	0	4	8	limit	1.000	641	**0.475**	0	0	0
	2575.79	582	0	2	18	2908.84	*1.129*	742	*1.235*	0	0	0
	1090.28	191	0	1	0	1119.62	1.027	353	*1.557*	0	0	0
	2314.80	566	0	3	6	1733.81	**0.749**	370	**0.706**	0	0	0
neos-933364	25.96	4170	0	2	8	24.26	**0.937**	3449	**0.831**	0	0	0
	50.52	20459	0	0	33	39.50	**0.786**	10318	**0.507**	0	0	0
	26.65	5057	0	0	15	35.71	*1.328*	8918	*1.749*	0	0	0
	92.50	32533	0	0	57	34.64	**0.381**	8041	**0.249**	0	0	0
neos-933550	3.32	27	0	0	0	3.34	1.005	27	1.000	0	0	0
	3.60	28	0	0	0	3.62	1.004	28	1.000	0	0	0
	3.68	31	0	0	0	3.67	0.998	31	1.000	0	0	0
	3.30	25	0	0	0	3.30	1.000	25	1.000	0	0	0
neos-933562	limit	50628	0	1	236	limit	1.000	50749	1.002	0	0	0
	limit	99087	0	0	383	limit	1.000	99087	1.000	0	0	0
	limit	33027	1	1	885	limit	1.000	33009	0.999	0	0	0
	limit	62222	0	1	427	limit	1.000	61869	0.994	0	0	0
neos-933638	6377.19	948	0	3	126	6259.03	0.981	1463	*1.491*	0	0	0
	2373.77	246	0	1	0	4902.29	*2.065*	419	*1.500*	0	0	0
	4796.62	907	0	2	57	4770.24	0.995	907	1.000	0	0	0
	3543.20	767	0	1	40	2848.87	**0.804**	425	**0.606**	0	0	0
neos-933815	25.65	12053	0	0	92	45.27	*1.736*	31016	*2.560*	1	1	29
	34.66	23405	1	1	64	22.43	**0.657**	9438	**0.406**	1	1	26
	31.24	15872	0	0	49	44.42	*1.409*	17432	*1.098*	0	0	0
	28.15	15493	0	1	65	18.65	**0.674**	4378	**0.287**	0	0	0
neos-933966	limit	2493	1	2	222	limit	1.000	2488	0.998	0	0	0
	1475.89	114	0	2	15	1481.38	1.004	114	1.000	0	0	0
	4475.20	1618	0	2	413	2622.26	**0.586**	1056	**0.673**	0	0	0
	2369.70	1091	0	1	107	5195.98	*2.192*	2611	*2.276*	0	0	0
neos-934278	limit	990	0	0	0	limit	1.000	913	**0.929**	0	0	0
	limit	2557	0	0	180	limit	1.000	2047	**0.808**	0	0	0
	limit	603	0	0	1	limit	1.000	800	*1.280*	0	0	0
	5918.44	2652	0	1	603	limit	*1.217*	919	**0.370**	0	0	0
neos-934441	limit	758	0	0	0	limit	1.000	619	**0.838**	0	0	0
	limit	2550	0	0	315	limit	1.000	1012	**0.420**	0	0	0
	limit	678	1	1	82	limit	1.000	794	*1.149*	0	0	0
	limit	1049	1	1	97	limit	1.000	1125	*1.066*	0	0	0
neos-934531	69.55	1	0	0	0	107.16	*1.533*	3	1.020	1	1	9
	103.31	2	0	0	0	109.81	*1.062*	8	*1.059*	0	0	10
	129.71	12	0	0	0	114.33	**0.882**	5	**0.938**	0	0	33
	99.23	10	0	0	0	82.84	**0.836**	2	**0.927**	0	0	30
neos-935234	limit	1283	0	0	132	limit	1.000	631	**0.529**	0	0	0
	limit	613	1	1	10	limit	1.000	566	**0.934**	0	0	0
	limit	882	2	2	17	limit	1.000	459	**0.569**	0	0	0
	limit	1692	0	1	327	limit	1.000	756	**0.478**	0	0	0
neos-935348	limit	736	3	3	664	limit	1.000	1190	*1.543*	0	0	0
	limit	633	0	1	5	limit	1.000	822	*1.258*	0	0	0
	limit	613	0	0	1	limit	1.000	3106	*4.496*	0	0	0
	limit	623	2	2	7	limit	1.000	581	**0.942**	0	0	0
neos-935496	limit	1635680	1	1	4511	limit	1.000	1636528	1.001	0	0	0
	limit	1100074	0	1	1794	limit	1.000	1103301	1.003	0	0	0
	limit	1044317	0	1	892	limit	1.000	1050846	1.006	0	0	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	1611305	0	0	941	limit	1.000	1606207	0.997	0	0	0
neos-935627	limit	698	1	1	424	limit	1.000	689	0.989	0	0	0
	limit	859	0	0	5	limit	1.000	666	**0.799**	0	0	0
	limit	805	2	2	15	5596.69	**0.777**	589	**0.761**	0	0	0
	limit	678	2	2	303	limit	1.000	783	*1.135*	0	0	0
neos-935674	limit	822413	4	4	4406	limit	1.000	823191	1.001	0	0	0
	limit	1207970	1	1	6383	limit	1.000	1199452	0.993	0	0	0
	limit	1113841	2	2	2095	limit	1.000	1115829	1.002	0	0	0
	limit	1624075	1	1	9117	limit	1.000	1620055	0.998	0	0	0
neos-935769	limit	1105	2	3	136	1645.51	**0.229**	171	**0.225**	0	0	0
	5326.90	4126	3	3	301	limit	*1.352*	1910	**0.476**	0	0	0
	limit	925	0	4	23	limit	1.000	2969	*2.994*	0	0	0
	2819.87	417	0	2	19	limit	*2.553*	917	*1.967*	0	0	0
neos-936660	limit	859	0	3	34	limit	1.000	720	**0.855**	0	0	0
	limit	522	0	2	20	limit	1.000	1841	*3.121*	0	0	0
	limit	1530	6	2	3	6013.22	**0.835**	1993	*1.284*	0	0	0
	limit	1955	2	2	117	limit	1.000	779	**0.428**	0	0	0
neos-937446	1107.70	263	2	1	0	limit	*6.495*	497	*1.645*	0	0	0
	limit	1807	1	2	149	4367.93	**0.607**	275	**0.197**	0	0	0
	limit	1443	6	2	174	5593.84	**0.777**	719	**0.531**	0	0	0
	limit	2046	0	1	154	1653.98	**0.230**	241	**0.159**	0	0	0
neos-937511	4538.90	1866	4	2	243	limit	*1.586*	878	**0.497**	0	0	0
	3227.43	896	2	2	177	limit	*2.230*	795	**0.899**	0	0	0
	limit	1318	2	1	209	2105.65	**0.293**	308	**0.288**	0	0	0
	5424.26	2031	3	3	297	5949.01	*1.097*	1377	**0.693**	0	0	0
neos-937815	limit	1116	2	2	405	limit	1.000	1288	*1.141*	0	0	0
	limit	959	2	2	231	limit	1.000	805	**0.855**	0	0	0
	limit	777	4	4	638	limit	1.000	3231	*3.798*	0	0	0
	limit	3047	0	2	46	limit	1.000	917	**0.323**	0	0	0
neos-941262	limit	822	0	0	12	limit	1.000	996	*1.189*	0	0	0
	limit	1002	0	2	80	limit	1.000	1054	1.047	0	0	0
	limit	1058	2	2	193	limit	1.000	1039	0.984	0	0	0
	limit	957	0	0	15	limit	1.000	806	**0.857**	0	0	0
neos-941313	6444.20	231	1	1	694	5046.92	**0.783**	213	**0.946**	0	0	0
	1035.95	5	0	0	0	1055.69	1.019	5	1.000	0	0	0
	656.30	6	0	0	0	930.27	*1.417*	6	1.000	0	0	0
	4470.37	185	0	0	0	5395.83	*1.207*	135	**0.825**	0	0	0
neos-941698	18.09	483	0	0	89	18.12	1.002	483	1.000	0	0	0
	8.67	71	0	0	0	8.68	1.001	71	1.000	0	0	0
	13.05	123	0	0	0	12.99	0.996	123	1.000	0	0	0
	11.52	99	0	0	0	11.45	0.994	99	1.000	0	0	0
neos-941717	limit	1209412	0	1	1410	limit	1.000	1207745	0.999	0	0	0
	limit	802081	2	0	1440	limit	1.000	805719	1.005	0	0	0
	limit	1440689	0	1	994	limit	1.000	1442169	1.001	0	0	0
	limit	1002180	1	1	4082	limit	1.000	999773	0.998	0	0	0
neos-941782	limit	1599312	1	1	39926	limit	1.000	1594395	0.997	0	0	0
	limit	1338700	1	1	3573	limit	1.000	1340471	1.001	0	0	0
	limit	1716801	1	1	5477	limit	1.000	1714903	0.999	0	0	0
	limit	1749924	0	1	3085	limit	1.000	1750043	1.000	0	0	0
neos-942323	3.31	30	0	0	0	3.28	0.993	30	1.000	0	0	0
	6.78	490	0	0	0	6.78	1.000	490	1.000	0	0	0
	4.44	97	0	0	0	4.46	1.004	97	1.000	0	0	0
	7.17	714	0	0	0	7.19	1.002	714	1.000	0	0	0
neos-942830	1123.59	384859	2	2	2611	1120.45	0.997	384859	1.000	0	0	0
	641.74	243577	0	0	2814	642.20	1.001	243577	1.000	0	0	0
	533.80	182134	1	1	4325	570.39	*1.068*	197328	*1.083*	0	0	0
	1127.30	308675	1	0	3734	1125.80	0.999	308675	1.000	0	0	0
neos-942886	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
neos-948126	limit	861	2	2	518	limit	1.000	1272	*1.428*	0	0	0
	limit	2203	0	0	418	limit	1.000	1130	**0.534**	0	0	0
	limit	955	0	0	6	limit	1.000	1009	*1.051*	0	0	0
	limit	1460	4	4	24	limit	1.000	1232	**0.854**	0	0	0
neos-948268	9.29	1	0	0	0	9.26	0.997	1	1.000	0	0	0
	12.53	1	0	0	0	12.58	1.004	1	1.000	0	0	0
	8.09	1	0	0	0	8.11	1.002	1	1.000	0	0	0
	10.88	1	0	0	0	10.84	0.997	1	1.000	0	0	0
neos-948346	limit	81	0	0	0	limit	1.000	157	*1.420*	0	0	0
	limit	393	0	0	71	limit	1.000	415	1.045	0	0	0
	limit	484	2	2	410	limit	1.000	394	**0.846**	0	0	0
	limit	269	0	0	0	limit	1.000	454	*1.501*	0	0	0
neos-950242	341.95	137	0	0	37	347.54	1.016	137	1.000	0	0	0
	233.01	62	0	0	64	237.47	1.019	62	1.000	0	0	0
	209.98	39	0	1	95	214.41	1.021	39	1.000	0	0	0
	589.70	194	0	0	154	604.03	1.024	194	1.000	0	0	0
neos-952987	limit	23	0	0	0	limit	1.000	22	0.992	0	0	0
	limit	30	0	0	0	limit	1.000	29	0.992	0	0	0
	limit	17	0	0	0	limit	1.000	16	0.991	0	0	0
	limit	36	0	0	8	limit	1.000	35	0.993	0	0	0
neos-953928	408.30	97	0	0	0	273.16	**0.670**	12	**0.569**	0	0	0
	354.82	72	1	1	2	318.61	**0.898**	81	*1.052*	0	0	0
	516.32	43	1	1	34	475.31	**0.921**	37	0.958	0	0	0
	673.51	69	1	0	62	483.91	**0.719**	55	**0.917**	0	0	0
neos-954925	5197.32	326	0	0	54	1721.07	**0.331**	41	**0.331**	0	0	0
	2374.11	93	0	0	0	1946.47	**0.820**	94	1.005	0	0	0
	2731.68	160	1	2	25	2638.98	0.966	105	**0.788**	0	0	0
	2066.39	41	0	0	0	1659.86	**0.803**	41	1.000	0	0	0
neos-955215	14.46	17654	0	0	94	11.99	**0.840**	15909	**0.902**	1	1	93
	12.49	7955	0	0	84	17.42	*1.365*	20418	*2.547*	0	0	0
	12.23	17102	0	0	103	22.77	*1.797*	32370	*1.888*	1	1	140
	6.66	3797	0	0	27	24.57	*3.338*	43400	*11.162*	1	1	106
neos-955800	55.67	2143	1	1	255	56.74	1.019	2143	1.000	0	0	0
	34.96	998	1	1	89	35.29	1.009	998	1.000	0	0	0
	29.61	707	0	0	21	29.63	1.001	707	1.000	0	0	0
	46.03	1323	0	0	229	46.20	1.004	1323	1.000	0	0	0
neos-956971	2892.23	284	0	2	31	2257.98	**0.781**	105	**0.534**	0	0	0
	6316.84	362	0	0	347	5772.68	**0.914**	290	**0.844**	0	0	0
	2641.42	694	1	1	151	3327.23	*1.260*	1100	*1.511*	0	0	0
	5438.21	382	1	1	34	1699.67	**0.313**	66	**0.344**	0	0	0
neos-957143	920.52	41	1	1	0	1025.69	*1.114*	52	*1.078*	0	0	0
	3612.96	318	0	1	12	1814.94	**0.502**	152	**0.603**	0	0	0
	4367.13	226	0	1	118	1612.60	**0.369**	124	**0.687**	0	0	0
	3425.20	319	3	3	100	3003.98	**0.877**	213	**0.747**	0	0	0
neos-957270	1.74	1	0	0	0	1.70	0.985	1	1.000	0	0	0
	1.69	1	0	0	0	1.75	1.022	1	1.000	0	0	0
	1.74	1	0	0	0	1.70	0.985	1	1.000	0	0	0
	1.72	1	0	0	0	1.72	1.000	1	1.000	0	0	0
neos-957323	93.90	2	0	0	0	116.55	*1.239*	1	0.990	0	0	0
	267.26	18	0	0	0	199.54	**0.748**	14	0.966	0	0	0
	105.49	3	0	0	0	153.13	*1.447*	5	1.019	1	1	0
	77.27	2	0	0	0	60.82	**0.790**	1	0.990	1	1	0
neos-957389	13.28	1	0	0	0	13.28	1.000	1	1.000	0	0	0
	13.30	1	0	0	0	13.34	1.003	1	1.000	0	0	0
	13.22	1	0	0	0	13.18	0.997	1	1.000	0	0	0
	13.45	1	0	0	0	13.31	0.990	1	1.000	0	0	0
neos-960392	678.00	15	0	0	0	698.82	1.031	15	1.000	0	0	0
	802.54	28	0	0	0	822.14	1.024	28	1.000	0	0	0
	1789.93	269	0	0	39	1852.85	1.035	269	1.000	0	0	0

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Table D.1: Computational results on MMMC: Farkas Diving over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	1080.45	58	0	1	280	1109.19	1.027	58	1.000	0	0	0
neos-983171	limit	601	0	0	5	limit	1.000	593	0.989	0	0	0
	limit	732	0	0	22	limit	1.000	664	**0.918**	0	0	0
	limit	762	3	3	221	limit	1.000	766	1.005	0	0	0
	limit	474	1	0	12	limit	1.000	533	*1.103*	0	0	0
neos-984165	limit	786	0	0	149	limit	1.000	681	**0.881**	0	0	0
	limit	628	5	5	388	limit	1.000	1299	*1.922*	0	0	0
	limit	759	0	0	8	limit	1.000	701	**0.932**	0	0	0
	limit	623	4	4	2	limit	1.000	685	*1.086*	0	0	0
neos13	482.46	23323	2	2	197	474.57	0.984	23323	1.000	0	0	0
	761.63	39311	2	2	214	760.94	0.999	39311	1.000	0	0	0
	95.77	1594	1	1	2	96.33	1.006	1594	1.000	0	0	0
	530.73	23947	0	0	163	539.48	1.016	23947	1.000	0	0	0
neos18	20.63	1291	0	0	50	20.52	0.995	1291	1.000	0	0	0
	21.66	1573	0	0	76	21.69	1.001	1573	1.000	0	0	0
	19.25	1011	0	0	26	19.26	1.000	1011	1.000	0	0	0
	18.67	946	0	0	9	18.39	0.986	946	1.000	0	0	0
net12	857.68	2252	0	0	621	577.95	**0.674**	1626	**0.734**	0	0	35
	758.16	1907	1	1	612	1345.64	*1.774*	2077	*1.085*	0	0	42
	2134.09	1799	0	1	481	515.95	**0.242**	1508	**0.847**	0	0	40
	3448.66	3677	1	1	627	851.71	**0.247**	3126	**0.854**	0	0	35
netdiversion	924.68	59	1	1	4	1592.73	*1.722*	175	*1.730*	0	0	0
	2209.03	66	0	0	26	3634.20	*1.645*	92	*1.157*	0	0	0
	4075.09	261	1	1	148	4527.40	*1.111*	159	**0.717**	0	0	0
	879.02	26	0	0	1	2058.06	*2.340*	76	*1.397*	0	0	0
newdano	6517.83	1459959	1	1	9	6565.08	1.007	1459959	1.000	0	0	0
	limit	1724750	0	0	1	limit	1.000	1713948	0.994	0	0	0
	6428.83	1316321	1	1	5	6467.54	1.006	1316321	1.000	0	0	0
	limit	1796696	2	4	12	limit	1.000	1786948	0.995	0	0	0
noswot	204.56	813210	1	1	685	204.00	0.997	813210	1.000	0	0	0
	146.65	590698	0	0	768	146.00	0.996	590698	1.000	0	0	0
	215.95	919828	0	0	1458	214.41	0.993	919828	1.000	0	0	0
	200.68	856222	0	0	864	201.04	1.002	856222	1.000	0	0	0
ns1208400	1051.70	3332	0	0	120	1045.17	0.994	3332	1.000	0	0	0
	319.22	827	0	0	86	318.38	0.997	827	1.000	0	0	0
	239.40	2522	0	0	484	239.25	0.999	2522	1.000	0	0	0
	503.66	2476	0	0	143	503.43	1.000	2476	1.000	0	0	0
ns1688347	36.78	254	0	0	10	50.86	*1.373*	432	*1.503*	0	0	54
	55.17	688	2	2	407	57.66	1.044	1558	*2.104*	0	0	0
	143.82	1063	1	1	684	158.40	*1.101*	991	**0.938**	0	0	81
	49.99	660	0	0	277	41.06	**0.825**	342	**0.582**	0	0	0
ns1758913	3939.24	2	0	0	0	4183.92	*1.062*	2	1.000	0	0	0
	1589.15	1	0	0	0	1588.55	1.000	1	1.000	0	0	0
	1695.14	1	0	0	0	1687.90	0.996	1	1.000	0	0	0
	1121.08	1	0	0	0	1135.71	1.013	1	1.000	0	0	0
ns1766074	596.68	889034	0	0	326	687.93	*1.153*	894838	1.007	0	0	2
	734.01	904416	0	0	554	617.77	**0.842**	887992	0.982	0	0	2
	608.71	901625	0	0	239	668.39	*1.098*	899355	0.997	0	0	2
	732.27	902421	0	0	447	741.87	1.013	898399	0.996	0	0	0
ns1830653	188.45	11159	1	1	1015	107.65	**0.574**	5799	**0.524**	0	0	12
	100.94	4245	1	1	547	165.12	*1.630*	8688	*2.023*	0	0	5
	136.13	7106	0	0	1075	117.70	**0.866**	6535	**0.921**	0	0	90
	140.84	4909	0	0	430	202.82	*1.437*	7919	*1.601*	0	0	5
nsa	1.74	226	0	1	0	1.72	0.993	226	1.000	0	0	0
	1.68	212	1	1	1	1.71	1.011	212	1.000	0	0	0
	1.74	191	0	1	2	1.77	1.011	191	1.000	0	0	0
	1.79	217	0	0	1	1.82	1.011	217	1.000	0	0	0
nsrand-ipx	586.58	83815	0	0	61	304.26	**0.520**	26960	**0.322**	0	0	0
	568.55	73290	0	0	44	357.04	**0.629**	43845	**0.599**	0	0	0
	877.30	113654	0	0	58	553.57	**0.631**	64093	**0.564**	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	353.86	41859	0	0	41	544.46	*1.537*	67105	*1.602*	0	0	0
nug08	124.94	3	0	0	0	187.38	*1.496*	2	0.990	1	1	5
	80.11	2	0	0	0	84.47	*1.054*	2	1.000	1	1	0
	179.72	4	0	0	0	183.85	1.023	2	0.981	1	1	4
	116.07	2	0	0	0	105.48	**0.910**	2	1.000	1	1	0
nw04	21.07	6	0	0	0	26.17	*1.231*	6	1.000	0	0	68
	21.58	6	0	0	0	22.42	1.037	6	1.000	1	1	89
	23.39	6	0	0	0	22.82	0.977	6	1.000	1	1	59
	32.31	9	0	0	0	22.47	**0.705**	5	0.963	1	1	93
opm2-z7-s2	337.53	3782	1	1	91	209.34	**0.621**	1527	**0.419**	1	1	309
	216.00	1576	0	0	0	275.74	*1.275*	3161	*1.946*	1	1	319
	260.46	1537	0	0	179	267.55	1.027	2509	*1.594*	1	1	103
	260.69	2091	1	1	206	248.42	0.953	2470	*1.173*	1	1	142
opt1217	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
p0033	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
p0201	0.50	3	0	0	0	0.51	1.007	5	1.019	1	1	5
	0.64	9	0	0	0	0.61	0.982	7	0.982	1	1	5
	0.67	9	0	0	0	0.66	0.994	7	0.982	0	0	11
	0.54	11	0	0	0	0.65	*1.071*	25	*1.126*	0	0	12
p0282	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	2
	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	2
	0.60	3	0	0	0	0.50	**0.938**	2	0.990	0	0	3
	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	2
p0548	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
p2756	4.69	5	0	0	0	3.98	**0.875**	12	*1.067*	1	1	2
	2.51	3	0	0	0	2.42	0.974	6	1.029	0	0	9
	3.28	27	0	0	1	3.14	0.967	14	**0.898**	0	0	9
	2.28	5	0	0	0	1.82	**0.860**	3	0.981	0	0	2
p6b	limit	736200	7	1	791	limit	1.000	727605	0.988	0	0	0
	limit	756588	3	1	525	limit	1.000	750070	0.991	0	0	0
	limit	718892	4	1	752	limit	1.000	710231	0.988	0	0	0
	limit	738033	2	1	323	limit	1.000	722445	0.979	0	0	0
pg5_34	4180.19	238659	0	0	1	4795.62	*1.147*	285214	*1.195*	1	1	3
	1165.49	236000	0	0	0	952.73	**0.818**	187700	**0.795**	1	1	2
	3500.68	225680	1	1	2	3332.84	0.952	215437	0.955	1	1	0
	2965.44	234406	1	1	1	2509.26	**0.846**	198989	**0.849**	1	1	9
pg	17.58	840	1	1	2	18.62	*1.056*	784	**0.940**	1	1	23
	27.09	599	1	1	2	27.47	1.014	580	0.973	1	1	13
	24.34	610	1	0	0	26.00	*1.066*	786	*1.248*	1	1	31
	15.85	195	0	0	6	21.56	*1.339*	304	*1.369*	1	1	16
pigeon-10	4549.68	13529494	0	0	2287	4525.24	0.995	13529494	1.000	0	0	0
	limit	21700928	0	0	8115	limit	1.000	21778322	1.004	0	0	0
	5295.04	13405990	0	0	6404	5311.40	1.003	13405990	1.000	0	0	0
	4440.38	13640551	0	0	2053	4422.90	0.996	13640551	1.000	0	0	0
pk1	127.38	403963	0	0	51	126.86	0.996	403963	1.000	0	0	0
	118.08	369445	0	0	46	117.84	0.998	369445	1.000	0	0	0
	117.61	366279	0	0	62	118.15	1.005	366279	1.000	0	0	0
	125.50	401727	0	0	49	125.45	1.000	401727	1.000	0	0	0
pp08a	1.86	282	2	0	0	1.51	**0.878**	182	**0.738**	32	1	8
	1.65	269	8	2	2	1.54	0.958	312	*1.117*	38	3	14
	1.55	164	3	0	3	1.27	**0.890**	71	**0.648**	30	2	18

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	1.14	116	3	0	2	1.30	*1.075*	227	*1.514*	26	4	17
pp08aCUTS	2.30	329	3	0	3	2.19	0.967	409	*1.186*	24	8	27
	2.20	282	7	2	7	1.63	**0.822**	98	**0.518**	25	3	9
	1.96	250	7	2	1	2.20	*1.081*	348	*1.280*	25	3	8
	2.03	226	0	0	5	2.01	0.993	253	*1.083*	31	2	5
prod1	20.42	30227	1	0	774	20.21	0.990	30227	1.000	0	0	0
	20.70	28677	1	0	913	20.54	0.993	28677	1.000	0	0	0
	15.84	22822	1	0	594	15.71	0.992	22822	1.000	0	0	0
	16.24	22930	1	0	407	16.08	0.991	22930	1.000	0	0	0
prod2	115.87	107994	2	1	584	114.96	0.992	107994	1.000	0	0	0
	80.28	71063	1	0	1046	80.05	0.997	71063	1.000	0	0	0
	86.55	91488	1	0	1006	86.03	0.994	91488	1.000	0	0	0
	108.22	108421	1	0	743	107.90	0.997	108421	1.000	0	0	0
protfold	limit	9753	0	0	745	limit	1.000	9909	1.016	0	0	0
	limit	10895	0	0	325	limit	1.000	10935	1.004	0	0	0
	limit	12737	0	1	487	limit	1.000	12779	1.003	0	0	0
	limit	20203	0	0	634	limit	1.000	19516	0.966	0	0	0
pw-myciel4	578.64	90247	1	1	8045	589.55	1.019	90247	1.000	0	0	0
	2232.67	348714	1	1	53137	2263.11	1.014	348714	1.000	0	0	0
	5814.04	645550	1	1	17899	5886.56	1.012	645550	1.000	0	0	0
	1954.66	238039	0	0	13994	1990.33	1.018	238039	1.000	0	0	0
qap10	68.39	5	0	0	0	87.20	*1.271*	5	1.000	0	0	0
	107.40	2	0	0	0	106.71	0.994	2	1.000	0	0	0
	177.29	14	0	0	0	208.39	*1.174*	12	0.982	0	0	0
	74.89	3	0	0	0	80.13	*1.069*	3	1.000	0	0	0
qiu	29.38	3841	6	2	9	29.19	0.994	3841	1.000	0	0	0
	16.49	2142	5	3	4	16.49	1.000	2142	1.000	0	0	0
	31.47	4087	18	5	18	31.67	1.006	4087	1.000	0	0	0
	36.36	4325	27	7	17	36.31	0.999	4325	1.000	0	0	0
qnet1	4.46	29	0	0	0	2.14	**0.575**	15	**0.891**	2	1	0
	7.41	5	0	0	0	4.71	**0.679**	2	0.971	0	0	13
	1.88	2	0	0	0	1.93	1.017	3	1.010	3	0	45
	4.10	24	0	0	0	2.20	**0.627**	7	**0.863**	4	1	39
qnet1_o	1.80	3	0	0	0	1.73	0.975	2	0.990	1	0	28
	2.62	12	0	0	0	2.81	*1.052*	17	1.045	0	0	0
	0.90	2	0	0	0	3.41	*2.321*	22	*1.196*	2	1	33
	1.05	1	0	0	0	1.47	*1.205*	2	1.010	4	0	20
rail507	140.85	631	0	0	0	441.23	*3.118*	1896	*2.731*	0	0	0
	171.32	807	0	0	4	210.77	*1.229*	1163	*1.393*	0	0	0
	218.31	900	0	0	4	270.79	*1.239*	1366	*1.466*	0	0	0
	186.65	847	0	0	4	183.88	0.985	938	*1.096*	0	0	0
ramos3	limit	39	0	0	0	limit	1.000	38	0.993	0	0	0
	limit	38	0	0	0	limit	1.000	37	0.993	0	0	0
	limit	43	0	0	0	limit	1.000	42	0.993	0	0	0
	limit	39	0	0	0	limit	1.000	39	1.000	0	0	0
ran14x18.disj-8	1538.55	422669	74	0	61	1402.69	**0.912**	345694	**0.818**	115	0	521
	1653.43	509529	143	0	80	1876.99	*1.135*	535668	*1.051*	125	0	646
	2687.47	791360	249	1	79	2194.19	**0.817**	572880	**0.724**	81	5	672
	3072.20	511977	184	1	125	1994.19	**0.649**	527306	1.030	103	0	526
ran14x18_1	1140.33	339134	167	0	47	905.95	**0.795**	280572	**0.827**	59	0	332
	1274.74	418898	104	0	52	1069.31	**0.839**	343078	**0.819**	48	0	312
	1395.02	497943	74	0	30	1069.47	**0.767**	402115	**0.808**	77	0	343
	1838.22	769180	275	0	100	1058.92	**0.576**	404079	**0.525**	47	0	228
ran16x16	78.39	14539	16	1	26	71.11	**0.908**	10926	**0.753**	48	0	100
	78.83	15549	38	0	38	89.10	*1.129*	18429	*1.184*	37	0	135
	61.78	7934	64	1	25	73.04	*1.179*	11819	*1.484*	43	0	126
	75.34	11547	83	0	57	62.20	**0.828**	12123	1.049	25	0	121
rd-rplusc-21	limit	566979	0	0	44	limit	1.000	465729	**0.821**	0	0	0
	limit	753532	1	1	56	limit	1.000	744800	0.988	0	0	0
	limit	753887	0	0	84	limit	1.000	749967	0.995	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	1078509	1	1	187	limit	1.000	1089420	1.010	0	0	0
reblock67	214.83	40539	0	0	1850	188.89	**0.880**	47653	*1.175*	0	0	4
	193.22	52781	1	1	4974	140.22	**0.727**	34966	**0.663**	0	0	1
	227.71	53944	2	2	4273	183.53	**0.807**	46416	**0.861**	0	0	4
	214.38	56714	1	1	3330	250.87	*1.169*	42468	**0.749**	0	0	2
rentacar	2.22	4	0	0	0	2.26	1.012	4	1.000	0	0	0
	2.18	2	0	0	0	2.14	0.987	2	1.000	0	0	0
	2.36	16	1	1	0	2.34	0.994	16	1.000	0	0	0
	2.20	14	1	1	0	2.24	1.012	14	1.000	0	0	0
rgn	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
rlp1	limit	31721997	0	0	88574	limit	1.000	31516821	0.994	0	0	0
	limit	32287071	0	0	199633	limit	1.000	32238909	0.999	0	0	0
	limit	25125732	0	0	38722	limit	1.000	25087758	0.998	0	0	0
	limit	35299868	0	0	141520	limit	1.000	35060214	0.993	0	0	0
rmatr100-p10	157.16	820	0	1	16	156.21	0.994	820	1.000	0	0	0
	167.23	807	2	2	19	166.10	0.993	807	1.000	0	0	0
	158.15	846	1	1	6	158.33	1.001	846	1.000	0	0	0
	169.70	852	2	2	11	168.63	0.994	852	1.000	0	0	0
rmatr100-p5	277.83	365	0	0	3	282.62	1.017	365	1.000	0	0	0
	285.10	409	0	0	4	315.14	*1.105*	487	*1.153*	0	0	0
	265.27	449	0	0	4	266.07	1.003	449	1.000	0	0	0
	286.80	405	0	0	3	281.08	0.980	405	1.000	0	0	0
rmine6	790.99	76215	0	0	251	960.92	*1.215*	106821	*1.401*	1	1	593
	807.84	60737	0	0	329	772.12	0.956	73431	*1.209*	0	0	0
	1048.96	121375	0	0	754	966.67	**0.922**	102970	**0.848**	2	2	733
	848.93	101031	0	0	584	859.03	1.012	89687	**0.888**	1	1	536
rocII-4-11	1352.53	4087	3	3	867	1538.22	*1.137*	10075	*2.430*	0	0	0
	1250.67	4222	5	5	1286	1280.96	1.024	7351	*1.724*	0	0	0
	1658.29	7462	3	3	1479	1492.59	**0.900**	9528	*1.273*	0	0	0
	1763.62	13470	3	2	2493	1482.29	**0.841**	4070	**0.307**	0	0	0
rococoC10-001000	1652.90	153256	0	0	240	1086.81	**0.658**	63391	**0.414**	0	0	55
	1047.00	75594	0	0	386	690.72	**0.660**	46888	**0.621**	0	0	114
	427.91	29811	0	0	115	407.34	0.952	32107	*1.077*	0	0	99
	914.09	56599	0	0	203	736.04	**0.805**	52061	**0.920**	0	0	92
roll3000	32.84	1664	0	0	11	46.33	*1.399*	2584	*1.522*	0	0	5
	64.07	4508	2	2	100	38.00	**0.599**	1373	**0.320**	0	0	7
	32.77	1440	0	0	26	45.61	*1.380*	2060	*1.403*	0	0	4
	79.96	4486	0	0	106	44.92	**0.567**	2708	**0.612**	0	0	7
rout	60.06	15767	2	2	233	77.41	*1.284*	21646	*1.371*	0	0	11
	78.59	19814	1	1	115	111.26	*1.410*	36853	*1.856*	1	1	464
	56.21	13029	1	1	210	51.41	**0.916**	13196	1.013	0	0	43
	61.31	13030	2	2	208	44.36	**0.728**	11848	**0.910**	0	0	101
roy	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	2	0	0	0	0.50	1.000	2	1.000	0	0	0
satellites1-25	943.35	2376	1	1	122	700.78	**0.743**	90	**0.077**	0	0	0
	740.49	817	1	1	62	779.41	*1.052*	273	**0.407**	2	2	87
	1237.17	2878	0	0	200	664.63	**0.538**	15	**0.039**	1	1	74
	1044.51	1159	1	1	38	964.13	**0.923**	817	**0.728**	2	2	118
set1ch	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	1	1	0
	0.50	2	0	0	0	0.50	1.000	2	1.000	53	3	0
seymour.disj-10	limit	78891	22	3	297	limit	1.000	78510	0.995	0	0	0
	limit	89879	18	2	284	limit	1.000	90466	1.007	0	0	0
	limit	96634	23	5	194	limit	1.000	96838	1.002	0	0	0

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	90321	12	2	204	limit	1.000	89977	0.996	0	0	0
seymour	limit	165661	15	3	474	limit	1.000	165633	1.000	0	0	0
	limit	271730	19	3	621	limit	1.000	270441	0.995	0	0	0
	limit	262802	11	2	430	limit	1.000	262187	0.998	0	0	0
	limit	229140	8	1	342	limit	1.000	229247	1.000	0	0	0
sp97ar	limit	29171	0	0	0	limit	1.000	30845	*1.057*	0	0	0
	limit	26740	0	0	0	limit	1.000	26461	0.990	0	0	0
	limit	33630	0	0	0	limit	1.000	31656	**0.941**	0	0	0
	limit	31991	0	0	0	limit	1.000	18966	**0.594**	0	0	0
sp97ic	limit	35605	0	0	85	limit	1.000	27668	**0.778**	0	0	0
	limit	57600	0	0	2	limit	1.000	53843	**0.935**	0	0	0
	limit	51639	0	0	4	limit	1.000	27616	**0.536**	0	0	0
	limit	26951	1	1	30	limit	1.000	31282	*1.160*	0	0	0
sp98ar	limit	2941	0	0	6	limit	1.000	3246	*1.100*	0	0	0
	limit	2717	1	1	4	limit	1.000	3529	*1.288*	0	0	0
	limit	2866	1	1	10	limit	1.000	3474	*1.205*	0	0	0
	limit	3091	1	1	16	limit	1.000	3279	*1.059*	0	0	0
sp98ic	limit	66210	0	0	0	limit	1.000	53121	**0.803**	0	0	0
	limit	45958	0	0	0	limit	1.000	50875	*1.107*	0	0	0
	limit	64998	0	0	0	limit	1.000	57426	**0.884**	0	0	0
	limit	57396	1	1	0	limit	1.000	67311	*1.172*	0	0	0
sp98ir	71.10	3218	0	0	103	81.48	*1.144*	5691	*1.745*	0	0	0
	66.48	4935	0	0	79	62.89	**0.947**	3820	**0.779**	0	0	0
	66.28	5009	0	0	110	61.61	**0.931**	3901	**0.783**	0	0	0
	55.54	4424	0	0	38	69.67	*1.250*	4134	**0.936**	0	0	0
stein27	0.70	1171	0	0	0	0.69	0.994	1171	1.000	0	0	0
	0.90	1785	0	0	0	0.85	0.974	1785	1.000	0	0	0
	0.50	537	0	0	0	0.50	1.000	537	1.000	0	0	0
	0.50	699	0	0	0	0.50	1.000	699	1.000	0	0	0
stein45	12.19	41379	1	0	0	12.16	0.998	41379	1.000	0	0	0
	12.49	40886	1	1	0	12.69	1.015	40886	1.000	0	0	0
	12.46	38979	0	0	0	12.49	1.002	38979	1.000	0	0	0
	12.72	41223	0	0	0	12.61	0.992	41223	1.000	0	0	0
stp3d	limit	17	0	0	0	limit	1.000	18	1.009	0	0	0
	limit	15	0	0	0	limit	1.000	14	0.991	0	0	0
	limit	18	0	0	0	limit	1.000	21	1.025	0	0	0
	limit	16	0	0	0	limit	1.000	14	0.983	0	0	0
swath	limit	508640	1	1	1265	limit	1.000	514879	1.012	0	0	0
	limit	379361	0	0	838	limit	1.000	628954	*1.658*	0	0	0
	limit	372015	0	0	966	limit	1.000	495371	*1.331*	0	0	0
	limit	372300	1	1	1330	limit	1.000	379923	1.020	0	0	0
t1717	limit	4315	3	0	957	limit	1.000	5305	*1.224*	0	0	45
	limit	5946	0	0	177	limit	1.000	5078	**0.856**	0	0	107
	limit	5743	0	0	234	limit	1.000	5061	**0.883**	0	0	13
	limit	5698	1	0	672	limit	1.000	5389	**0.947**	0	0	13
tanglegram1	537.62	53	0	0	0	543.98	1.012	53	1.000	0	0	0
	748.76	117	0	0	47	754.80	1.008	117	1.000	0	0	0
	611.08	75	0	0	75	609.37	0.997	75	1.000	0	0	0
	521.08	61	0	0	59	519.79	0.998	61	1.000	0	0	0
tanglegram2	5.21	3	0	0	0	5.22	1.002	3	1.000	0	0	0
	4.97	3	0	0	0	4.97	1.000	3	1.000	0	0	0
	5.22	3	0	0	0	5.29	1.011	3	1.000	0	0	0
	5.31	3	0	0	0	5.33	1.003	3	1.000	0	0	0
timtab1	59.41	49976	2	2	175	57.79	0.973	46773	**0.936**	0	0	4
	40.73	30772	2	2	233	55.42	*1.352*	42284	*1.373*	0	0	16
	53.86	44702	4	4	295	57.94	*1.074*	43625	0.976	0	0	24
	46.05	39788	1	1	188	48.43	*1.051*	33893	**0.852**	0	0	5
timtab2	limit	3067980	0	0	511	limit	1.000	3081653	1.004	0	0	9
	limit	2748872	1	1	399	limit	1.000	3262820	*1.187*	0	0	8
	limit	3889940	3	0	476	limit	1.000	3122712	**0.803**	0	0	31

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Table D.1: Computational results on MMMC: FARKAS DIVING over four random seeds.

	default					farkdiving						
Instance	T	N	F_{virt}	I_{virt}	C_{virt}	T	T_Q	N	N_Q	F	I	C
	limit	2816185	1	2	427	limit	1.000	3174571	*1.127*	0	0	4
tr12-30	795.56	520717	2	2	317	496.93	**0.625**	318400	**0.612**	0	0	10
	699.66	462981	0	2	417	499.26	**0.714**	325872	**0.704**	0	0	7
	987.48	595373	0	2	93	852.11	**0.863**	549538	**0.923**	0	0	12
	553.48	309327	0	0	99	599.30	*1.083*	344531	*1.114*	0	0	0
triptim1	1261.60	7	0	0	0	878.99	**0.697**	4	0.972	2	2	2
	687.77	8	0	0	0	838.17	*1.218*	11	1.028	0	0	0
	481.44	4	0	0	0	666.87	*1.384*	6	1.019	0	0	0
	881.96	41	0	0	0	253.87	**0.289**	1	**0.716**	1	1	0
unitcal_7	284.42	155	0	0	0	252.30	**0.887**	9	**0.427**	2	2	199
	374.73	356	0	0	0	254.69	**0.681**	9	**0.239**	3	3	1724
	410.88	377	1	1	8	325.55	**0.793**	87	**0.392**	1	1	209
	378.52	572	0	0	6	379.55	1.003	198	**0.443**	1	1	230
vpm1	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
	0.50	1	0	0	0	0.50	1.000	1	1.000	0	0	0
vpm2	2.44	264	0	0	0	3.07	*1.183*	289	*1.069*	0	0	38
	2.22	257	0	0	6	2.53	*1.096*	360	*1.289*	0	0	24
	1.53	230	0	0	0	2.46	*1.368*	115	**0.652**	0	0	21
	2.36	233	0	0	11	2.27	0.973	254	*1.063*	0	0	12
vpphard	limit	2069	0	2	4489	limit	1.000	2209	*1.065*	0	0	0
	limit	2501	1	1	6040	limit	1.000	4378	*1.722*	0	0	0
	limit	5184	1	1	13377	limit	1.000	7018	*1.347*	0	0	0
	limit	7485	2	5	5348	limit	1.000	3271	**0.444**	0	0	0
zib54-UUE	1705.36	76321	14	13	35	1559.33	**0.914**	57764	**0.757**	71	15	34
	1200.19	46323	12	9	24	1242.27	1.035	59899	*1.292*	52	11	46
	1894.37	74518	27	14	31	2275.42	*1.201*	88909	*1.193*	82	12	53
	1630.16	88765	11	2	33	1303.98	**0.800**	61000	**0.688**	47	12	37

Table D.2: Computational results on MMMC: Conflict Diving Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
10teams	23.7	359	22.8	0.963	395	*1.078*	0	13	343.0	18.3	**0.782**	151	**0.547**	0	106	65.0
	21.2	567	22.5	*1.058*	867	*1.450*	0	27	90.5	18.0	**0.856**	235	**0.502**	0	8	48.0
	4.4	5	4.4	1.000	5	1.000	0	0	0.0	4.5	1.002	5	1.000	0	0	0.0
	21.6	433	21.2	0.981	404	**0.946**	0	15	70.0	16.0	**0.753**	64	**0.308**	0	39	94.0
22433	3.4	3	2.9	**0.890**	3	1.000	0	0	0.0	3.4	1.002	3	1.000	0	0	0.0
	4.2	4	4.2	1.006	4	1.000	0	0	0.0	4.2	1.002	4	1.000	0	0	0.0
	2.6	3	2.7	1.011	3	1.000	0	0	0.0	2.6	1.000	3	1.000	0	0	0.0
	5.4	26	5.4	1.006	26	1.000	0	32	36.0	5.5	1.013	26	1.000	0	5	55.0
23588	6.0	495	5.2	**0.878**	495	1.000	0	0	0.0	5.7	**0.947**	495	1.000	0	0	0.0
	5.4	514	5.6	1.037	535	1.034	0	0	0.0	5.5	1.022	535	1.034	0	0	0.0
	4.6	336	6.4	*1.323*	730	*1.904*	0	0	0.0	6.4	*1.326*	730	*1.904*	0	0	0.0
	5.3	563	5.4	1.017	563	1.000	0	0	0.0	5.7	*1.065*	563	1.000	0	0	0.0
30n20b8	502.9	403	437.1	**0.869**	227	**0.650**	0	20	210.0	308.0	**0.613**	124	**0.445**	1	0	18.0
	244.1	96	321.8	*1.317*	144	*1.245*	0	7	373.5	258.5	*1.059*	108	*1.061*	0	16	227.0
	237.2	126	281.3	*1.185*	174	*1.212*	1	26	79.3	638.2	*2.683*	588	*3.044*	0	77	41.5
	468.5	284	683.8	*1.458*	331	*1.122*	1	19	140.0	641.3	*1.368*	373	*1.232*	1	15	41.8
Test3	5.7	4	5.5	0.975	4	1.000	0	0	0.0	5.7	0.996	4	1.000	0	0	0.0
	5.4	3	5.5	1.008	3	1.000	0	0	0.0	5.4	1.002	3	1.000	0	0	0.0
	5.5	2	5.4	0.994	2	1.000	0	0	0.0	5.5	1.002	2	1.000	0	0	0.0
	5.1	1	5.0	0.997	1	1.000	0	0	0.0	5.0	0.993	1	1.000	0	0	0.0
a1c1s1	limit	139641	limit	1.000	163793	*1.173*	0	19	54.6	limit	1.000	164552	*1.178*	0	4	27.8
	limit	162719	limit	1.000	163660	1.006	0	12	36.0	limit	1.000	201514	*1.238*	0	5	35.6
	limit	158245	limit	1.000	179111	*1.132*	0	22	37.1	limit	1.000	183541	*1.160*	0	2	37.2
	limit	161284	limit	1.000	150201	**0.931**	0	14	48.9	limit	1.000	137176	**0.851**	0	6	31.7
acc-tight5	135.3	940	129.6	0.958	744	**0.812**	0	257	23.5	121.8	**0.901**	627	**0.699**	0	231	25.5
	132.7	704	62.6	**0.476**	159	**0.322**	0	25	19.5	118.6	**0.894**	558	**0.818**	0	149	25.3
	118.5	498	199.9	*1.681*	1168	*2.120*	0	175	25.3	146.8	*1.237*	901	*1.674*	0	339	25.7
	109.3	599	119.9	*1.096*	645	*1.066*	0	199	21.6	130.4	*1.191*	717	*1.169*	1	243	20.1
aflow30a	34.3	751	28.0	**0.821**	873	*1.143*	0	0	0.0	29.4	**0.860**	735	0.981	0	3	31.0
	24.9	1046	23.6	**0.949**	503	**0.526**	0	0	0.0	25.3	1.015	1046	1.000	0	0	0.0
	22.0	473	25.8	*1.167*	582	*1.190*	0	0	0.0	25.9	*1.169*	657	*1.321*	0	0	0.0
	19.7	474	18.0	**0.916**	715	*1.420*	0	0	0.0	22.6	*1.142*	770	*1.516*	0	0	0.0
aflow40b	791.7	23244	898.5	*1.135*	24637	*1.060*	0	53	33.8	555.9	**0.703**	20128	**0.867**	0	26	82.2
	389.9	7966	732.9	*1.878*	19980	*2.489*	0	133	26.1	771.0	*1.975*	18675	*2.328*	0	28	74.0
	485.0	10919	704.6	*1.452*	22701	*2.069*	0	99	30.1	782.0	*1.611*	19320	*1.762*	0	46	55.4

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Table D.2: Computational results on MMMC: CONFLICT DIVING

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	729.3	28492	491.1	**0.674**	9715	**0.343**	0	130	24.0	598.8	**0.821**	16816	**0.592**	0	0	64.4
air03	2.6	1	2.4	0.958	1	1.000	0	0	0.0	2.7	1.042	1	1.000	0	0	0.0
	2.3	1	2.2	0.973	1	1.000	0	0	0.0	2.2	0.976	1	1.000	0	0	0.0
	2.3	1	2.3	1.009	1	1.000	0	0	0.0	2.3	0.997	1	1.000	0	0	0.0
	2.3	1	2.2	0.991	1	1.000	0	0	0.0	2.3	0.997	1	1.000	0	0	0.0
air04	49.1	110	49.3	1.005	110	1.000	0	0	0.0	49.0	0.999	110	1.000	0	0	0.0
	60.6	192	60.8	1.003	192	1.000	0	15	37.0	59.9	0.989	192	1.000	0	11	58.0
	47.2	107	47.2	1.001	107	1.000	0	6	49.0	47.2	1.000	107	1.000	0	11	35.0
	71.1	179	72.1	1.014	315	*1.487*	0	0	30.0	70.8	0.995	290	*1.398*	0	13	30.0
air05	33.5	342	46.9	*1.391*	798	*2.032*	0	0	221.0	43.7	*1.296*	663	*1.726*	0	0	221.0
	44.8	743	44.8	1.000	743	1.000	0	0	0.0	44.6	0.996	743	1.000	0	0	0.0
	34.8	422	34.7	0.997	422	1.000	0	0	0.0	34.9	1.004	422	1.000	0	0	0.0
	29.9	160	29.9	1.001	160	1.000	0	0	0.0	30.0	1.005	160	1.000	0	0	0.0
aligninq	29.7	1487	42.7	*1.426*	3320	*2.155*	0	2000	64.1	28.9	0.974	1751	*1.166*	0	94	96.8
	18.7	583	37.5	*1.954*	2875	*4.356*	0	1783	85.5	39.3	*2.044*	2602	*3.956*	0	203	76.5
	34.0	1948	29.7	**0.879**	1700	**0.879**	0	1713	70.5	22.7	**0.679**	1097	**0.584**	0	0	65.0
	36.7	2535	38.9	*1.059*	3044	*1.193*	0	743	58.1	26.6	**0.732**	1782	**0.714**	0	99	76.0
app1-2	927.5	26	924.6	0.997	26	1.000	0	0	0.0	927.8	1.000	26	1.000	0	0	0.0
	826.6	26	826.4	1.000	26	1.000	0	0	0.0	828.6	1.002	26	1.000	0	0	0.0
	1159.4	42	1157.0	0.998	42	1.000	0	0	0.0	1162.1	1.002	42	1.000	0	0	0.0
	974.9	20	983.5	1.009	20	1.000	0	0	0.0	979.8	1.005	20	1.000	0	0	0.0
arki001	limit	869267	limit	1.000	963881	*1.109*	0	60	86.0	limit	1.000	1423071	*1.637*	0	35	79.0
	limit	922587	limit	1.000	961059	1.042	0	40	109.9	limit	1.000	1124028	*1.218*	0	37	82.7
	limit	710068	limit	1.000	905037	*1.275*	0	20	100.7	limit	1.000	944689	*1.330*	0	56	93.0
	limit	871129	limit	1.000	1002063	*1.150*	0	53	95.7	limit	1.000	1186261	*1.362*	0	41	83.2
ash608gpia-3col	43.0	5	43.4	1.007	5	1.000	0	0	0.0	43.3	1.005	5	1.000	0	0	0.0
	36.7	11	38.9	*1.060*	11	1.000	0	0	0.0	36.6	0.999	11	1.000	0	0	0.0
	24.1	3	24.1	1.000	3	1.000	0	0	0.0	24.1	1.000	3	1.000	0	0	0.0
	35.7	11	35.7	1.001	11	1.000	0	0	0.0	35.5	0.995	11	1.000	0	0	0.0
atlanta-ip	limit	9729	limit	1.000	12741	*1.306*	0	2638	84.2	limit	1.000	27709	*2.829*	0	425	41.4
	limit	10022	limit	1.000	10450	1.042	0	1089	64.6	limit	1.000	12117	*1.207*	0	184	40.1
	limit	8721	limit	1.000	10784	*1.234*	0	1522	71.5	limit	1.000	6675	**0.768**	0	307	51.0
	limit	6036	limit	1.000	10070	*1.657*	0	1284	70.3	limit	1.000	7798	*1.287*	0	158	45.9
bab5	limit	68217	limit	1.000	66855	0.980	0	726	55.3	limit	1.000	67293	0.986	0	309	88.2
	limit	72828	limit	1.000	86126	*1.182*	0	178	48.0	limit	1.000	60153	**0.826**	0	420	97.9
	limit	108379	limit	1.000	79575	**0.734**	0	169	54.3	6816.9	**0.947**	92316	**0.852**	0	526	89.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	75445	limit	1.000	71305	**0.945**	0	162	67.2	limit	1.000	71561	**0.949**	0	235	81.7
bc1	200.5	1303	298.1	*1.485*	3870	*2.830*	0	0	51.0	242.2	*1.207*	3086	*2.271*	0	0	44.0
	304.7	4540	267.1	**0.877**	4006	**0.885**	0	0	59.0	325.1	*1.067*	5000	*1.099*	0	0	36.3
	234.9	1530	235.2	1.001	1600	1.043	0	0	64.0	229.2	0.976	1290	**0.853**	0	1	50.0
	258.9	3516	245.1	**0.947**	3422	0.974	0	0	61.0	286.0	*1.104*	4610	*1.303*	0	0	64.0
bc	1379.1	14573	1114.3	**0.808**	11703	**0.804**	0	0	49.7	1266.7	**0.919**	12122	**0.833**	0	6	45.0
	1125.2	12204	1242.7	*1.104*	11588	**0.950**	0	5	48.0	1132.3	1.006	12713	1.041	0	6	50.7
	1460.7	16681	1143.6	**0.783**	13849	**0.831**	0	0	43.8	1178.5	**0.807**	12413	**0.746**	0	6	47.7
	1557.5	19797	1130.2	**0.726**	13103	**0.664**	0	0	58.1	1075.3	**0.691**	13099	**0.663**	0	1	47.5
beasleyC3	59.1	311	58.6	0.992	378	*1.163*	0	0	81.0	57.6	0.976	378	*1.163*	0	0	88.0
	56.9	206	68.3	*1.196*	515	*2.010*	0	2	117.0	43.3	**0.765**	11	**0.363**	0	0	0.0
	54.2	485	56.0	1.033	170	**0.462**	0	0	0.0	57.0	*1.051*	170	**0.462**	0	0	0.0
	21.9	2	21.4	0.980	2	1.000	0	0	0.0	21.9	1.003	2	1.000	0	0	0.0
bell3a	2.0	3548	1.4	**0.797**	2445	**0.698**	15	16	18.1	1.2	**0.753**	1693	**0.492**	15	3	15.3
	1.4	3440	0.9	**0.808**	2184	**0.645**	12	21	18.7	1.4	1.004	3565	1.035	12	19	18.2
	1.9	4949	1.3	**0.801**	3116	**0.637**	15	16	17.9	1.0	**0.696**	2001	**0.416**	17	9	16.5
	1.8	4568	1.2	**0.795**	2720	**0.604**	15	15	16.6	1.5	**0.906**	4083	**0.896**	15	7	17.2
bell5	0.6	415	1.0	*1.299*	444	*1.056*	11	3	11.7	0.9	*1.223*	412	0.994	8	11	11.5
	0.6	511	0.5	0.968	339	**0.718**	8	2	11.8	0.5	0.968	339	**0.718**	8	2	11.5
	0.5	206	0.5	1.000	196	0.967	6	13	13.8	0.5	1.000	198	0.974	10	6	13.8
	0.6	410	0.6	0.987	451	*1.080*	11	5	11.3	0.5	0.969	435	1.049	13	14	12.0
biella1	1178.2	4348	1566.0	*1.329*	8151	*1.855*	0	20	310.1	1624.0	*1.378*	5962	*1.363*	0	0	267.0
	1283.7	3033	1246.4	0.971	5954	*1.932*	0	10	205.8	573.0	**0.447**	1563	**0.531**	0	24	127.6
	634.4	1580	997.2	*1.571*	1975	*1.235*	0	1	195.8	759.2	*1.196*	2159	*1.345*	0	2	229.8
	806.3	1684	1223.1	*1.516*	4551	*2.607*	0	2	194.5	1153.4	*1.430*	3849	*2.214*	0	0	240.7
bienst1	204.6	25970	155.0	**0.759**	16090	**0.621**	0	22	17.7	116.0	**0.569**	11409	**0.441**	2	38	19.5
	196.8	20587	121.4	**0.619**	9901	**0.483**	0	20	17.3	123.1	**0.627**	10018	**0.489**	2	46	18.6
	153.6	13823	125.8	**0.820**	9304	**0.675**	1	53	16.9	134.5	**0.877**	12736	**0.922**	1	21	17.7
	160.2	16868	147.1	**0.919**	15248	**0.905**	0	18	18.1	174.4	*1.088*	19016	*1.127*	0	7	20.3
bienst2	812.5	88717	658.5	**0.811**	62497	**0.705**	0	19	17.3	607.4	**0.748**	58870	**0.664**	0	4	23.0
	669.8	65095	743.3	*1.110*	81035	*1.244*	0	11	17.9	658.1	0.983	67204	1.032	1	12	22.3
	704.0	73577	600.4	**0.853**	62789	**0.854**	1	23	17.8	667.4	**0.948**	71954	0.978	2	10	21.9
	580.0	58053	581.4	1.003	60072	1.035	0	11	17.8	518.8	**0.895**	50864	**0.876**	0	1	22.9
binkar10_1	34.6	2288	34.2	0.988	2435	*1.062*	0	0	39.4	36.4	1.049	2407	1.050	0	4	34.1
	36.9	2311	49.6	*1.336*	2686	*1.156*	0	0	37.4	50.6	*1.361*	3100	*1.327*	0	6	39.5
	66.6	4312	29.0	**0.444**	1927	**0.459**	0	6	43.1	35.2	**0.536**	2480	**0.585**	0	8	38.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving							
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$	
	28.8	1795	46.6	*1.600*	4380	*2.364*	0	18	42.4	36.5	*1.260*	2172	*1.199*	0	3	41.9	
blend2	1.2	686	1.5	*1.113*	706	1.025	0	2	37.3	0.9	**0.856**	551	**0.828**	0	4	26.0	
	1.5	1042	1.2	**0.911**	832	**0.816**	0	14	30.7	1.6	*1.053*	1170	*1.112*	0	13	23.0	
	1.3	876	1.1	**0.896**	635	**0.753**	0	3	52.0	1.1	**0.931**	760	**0.881**	0	10	19.6	
	1.0	692	1.1	1.030	592	**0.874**	0	2	53.7	0.9	**0.936**	613	**0.900**	0	4	25.5	
bley_xl1	199.5	1	199.6	1.000	1	1.000	0	0	0.0	199.2	0.999	1	1.000	0	0	0.0	
	239.3	28	238.2	0.996	28	1.000	0	0	0.0	238.3	0.996	28	1.000	0	0	0.0	
	162.4	1	162.6	1.001	1	1.000	0	0	0.0	163.1	1.004	1	1.000	0	0	0.0	
	164.6	1	164.7	1.000	1	1.000	0	0	0.0	164.7	1.001	1	1.000	0	0	0.0	
bnatt350	1029.8	9977	857.7	**0.833**	4220	**0.429**	0	403	22.0	372.7	**0.363**	3060	**0.314**	0	361	21.6	
	662.4	5721	1063.6	*1.605*	7468	*1.300*	0	735	20.7	849.0	*1.281*	8212	*1.428*	0	1018	19.4	
	343.2	2444	538.7	*1.568*	4560	*1.832*	0	563	20.8	706.5	*2.056*	3739	*1.509*	0	814	17.8	
	827.2	8260	528.2	**0.639**	3663	**0.450**	0	605	21.2	1181.5	*1.428*	9914	*1.198*	0	954	19.5	
cap6000	4.4	2159	3.7	**0.866**	1978	**0.920**	5	14	18.7	4.1	**0.937**	1653	**0.776**	16	28	18.8	
	3.9	2269	3.5	**0.913**	1668	**0.746**	1	27	14.4	3.4	**0.895**	1568	**0.704**	1	28	14.5	
	4.5	2522	4.2	0.956	2113	**0.844**	6	29	17.5	4.2	0.954	2008	**0.804**	6	21	18.2	
	4.5	2579	4.2	0.951	2086	**0.816**	7	44	20.5	3.9	**0.882**	1693	**0.669**	12	20	18.1	
core2536-691	324.4	186	158.3	**0.490**	118	**0.762**	0	0	592.0	151.7	**0.469**	97	**0.689**	0	0	489.0	
	269.9	156	152.4	**0.566**	174	*1.070*	0	0	533.0	173.3	**0.643**	92	**0.750**	0	0	907.0	
	507.7	458	115.3	**0.229**	60	**0.287**	0	0	420.0	239.1	**0.472**	235	**0.600**	0	0	669.5	
	337.2	250	120.6	**0.360**	126	**0.646**	0	0	545.0	379.4	*1.125*	281	*1.089*	0	1	641.2	
cov1075	80.7	19859	81.9	1.015	19799	0.997	0	18	33.4	81.6	1.012	19679	0.991	0	7	39.1	
	111.1	33279	111.3	1.002	32317	0.971	0	50	36.0	119.0	*1.070*	35808	*1.076*	1	16	45.4	
	78.6	19252	63.5	**0.809**	13662	**0.711**	0	23	37.4	69.8	**0.889**	17223	**0.895**	1	14	39.7	
	78.9	17553	94.3	*1.192*	23085	*1.313*	1	20	38.7	83.5	*1.058*	19095	*1.087*	2	8	41.2	
csched010	5095.1	172718	limit	*1.413*	313276	*1.813*	0	171	82.5	6794.3	*1.333*	297025	*1.719*	0	266	72.5	
	limit	336948	limit	1.000	335172	0.995	0	239	61.1	limit	1.000	348991	1.036	0	191	76.3	
	2383.9	108940	4277.0	*1.794*	212064	*1.946*	0	239	71.2	3528.1	*1.480*	140492	*1.289*	0	84	88.0	
	4625.1	183497	6290.6	*1.360*	271887	*1.481*	0	392	59.7	3899.8	**0.843**	165525	**0.902**	0	139	45.9	
d10200	limit	949723	limit	1.000	817747	**0.861**	0	0	98.6	limit	1.000	1140208	*1.201*	0	0	86.2	
	limit	639641	limit	1.000	728898	*1.140*	0	2	101.2	limit	1.000	1033964	*1.616*	0	0	93.9	
	limit	956242	limit	1.000	725480	**0.759**	0	1	92.6	limit	1.000	634865	**0.664**	0	32	95.3	
	limit	735101	limit	1.000	794308	*1.081*	0	19	96.3	limit	1.000	1074686	*1.462*	0	51	98.4	
d20200	limit	245588	limit	1.000	292097	*1.189*	0	4	250.4	limit	1.000	261944	*1.067*	0	0	146.7	
	limit	223033	limit	1.000	258910	*1.161*	0	18	240.9	limit	1.000	230097	1.032	0	104	137.9	
	limit	236734	limit	1.000	219161	**0.926**	0	7	228.3	limit	1.000	204573	**0.864**	0	0	156.5	

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	230081	limit	1.000	256678	*1.116*	0	14	218.9	limit	1.000	273200	*1.187*	0	108	149.2
dano3_3	153.5	18	164.8	*1.073*	18	1.000	0	0	11.0	153.6	1.001	18	1.000	0	1	12.0
	132.6	6	132.6	0.999	6	1.000	0	0	0.0	132.9	1.002	6	1.000	0	0	0.0
	147.1	14	147.2	1.001	14	1.000	0	0	0.0	147.7	1.004	14	1.000	0	0	0.0
	144.4	12	144.8	1.003	12	1.000	0	0	0.0	144.8	1.002	12	1.000	0	0	0.0
dano3_4	193.7	14	193.6	1.000	14	1.000	0	0	0.0	193.1	0.997	14	1.000	0	0	0.0
	185.6	8	183.9	0.991	8	1.000	0	0	0.0	184.4	0.994	8	1.000	0	0	0.0
	169.2	14	168.8	0.998	14	1.000	0	1	7.0	168.8	0.997	14	1.000	0	0	9.0
	140.9	24	141.7	1.006	29	1.040	0	0	8.0	139.4	0.989	23	0.992	0	1	16.0
dano3_5	377.1	165	402.2	*1.067*	185	*1.075*	0	1	17.2	452.4	*1.199*	231	*1.249*	0	1	22.5
	455.6	174	415.8	**0.913**	156	**0.934**	0	7	20.0	363.1	**0.798**	177	1.011	0	3	26.5
	373.7	165	363.5	0.973	132	**0.875**	1	2	12.0	370.5	0.991	185	*1.075*	0	4	20.3
	480.7	167	386.6	**0.805**	176	1.034	0	1	19.0	406.0	**0.845**	220	*1.199*	0	2	28.3
dano3mip	limit	1397	limit	1.000	1420	1.015	0	4	47.3	limit	1.000	1366	0.979	0	0	271.2
	limit	1009	limit	1.000	957	0.953	0	5	39.4	limit	1.000	988	0.981	0	4	289.0
	limit	861	limit	1.000	630	**0.760**	0	4	42.6	limit	1.000	905	1.046	0	0	0.0
	limit	1263	limit	1.000	1493	*1.169*	0	2	45.0	limit	1.000	1570	*1.225*	0	0	0.0
danoint	4796.5	1277825	5129.3	*1.069*	1425342	*1.115*	0	0	23.1	4346.7	**0.906**	1182965	**0.926**	0	6	25.4
	4169.9	1146923	4795.3	*1.150*	1364472	*1.190*	0	1	23.9	4222.2	1.013	1127024	0.983	0	0	29.5
	5281.1	1463654	4399.2	**0.833**	1195273	**0.817**	0	2	24.6	5483.2	1.038	1527619	1.044	0	0	29.3
	2857.8	770103	3811.9	*1.334*	1062058	*1.379*	0	3	23.4	3398.3	*1.189*	948182	*1.231*	0	0	28.8
dcmulti	3.9	52	3.6	**0.945**	52	1.000	0	0	0.0	3.6	**0.949**	52	1.000	0	0	0.0
	3.5	71	3.6	1.002	71	1.000	0	0	0.0	3.6	1.007	71	1.000	0	0	0.0
	2.8	69	2.8	1.003	69	1.000	0	0	0.0	2.8	1.016	69	1.000	0	0	0.0
	3.0	82	3.0	0.990	82	1.000	0	0	0.0	3.1	1.017	82	1.000	0	0	0.0
dfn-gwin-UUM	124.1	23097	185.2	*1.489*	39788	*1.720*	8	10	42.8	134.4	*1.083*	25605	*1.108*	5	22	43.0
	133.8	27565	126.1	**0.943**	24607	**0.893**	6	13	44.9	123.2	**0.921**	23743	**0.862**	6	14	41.5
	134.2	25438	159.6	*1.188*	32088	*1.260*	6	13	45.5	169.8	*1.264*	35447	*1.392*	6	5	44.5
	108.4	21920	134.3	*1.237*	24146	*1.101*	6	16	42.3	115.6	*1.066*	21853	0.997	9	18	47.0
disctom	6.9	1	7.0	1.004	1	1.000	0	0	0.0	7.1	1.024	1	1.000	0	0	0.0
	7.2	1	7.2	0.998	1	1.000	0	0	0.0	7.2	1.000	1	1.000	0	0	0.0
	5.8	1	5.8	0.996	1	1.000	0	0	0.0	5.8	1.000	1	1.000	0	0	0.0
	9.2	1	9.2	0.994	1	1.000	0	0	0.0	9.2	0.998	1	1.000	0	0	0.0
ds	limit	1012	limit	1.000	637	**0.663**	14	0	64.0	limit	1.000	1012	1.000	0	0	0.0
	limit	845	limit	1.000	978	*1.141*	3	0	67.5	limit	1.000	750	**0.899**	0	34	138.5
	limit	875	limit	1.000	846	0.970	17	0	67.4	limit	1.000	851	0.975	0	0	123.5

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Table D.2: Computational results on MMMC: CONFLICT DIVING

	nolockdiving		coefdiving							confdiving						
Instance	**T**	**N**	**T**	$\mathbf{T_Q}$	**N**	$\mathbf{N_Q}$	**F**	**C**	$\mathbf{D_\emptyset}$	**T**	$\mathbf{T_Q}$	**N**	$\mathbf{N_Q}$	**F**	**C**	$\mathbf{D_\emptyset}$
	limit	766	limit	1.000	661	**0.879**	12	0	50.7	limit	1.000	766	1.000	0	0	0.0
dsbmip	2.3	16	2.1	**0.939**	16	1.000	0	0	0.0	2.5	*1.067*	16	1.000	0	0	0.0
	1.9	46	1.6	**0.914**	27	**0.870**	1	0	19.0	1.7	**0.938**	30	**0.890**	1	0	42.0
	1.8	16	1.8	1.011	16	1.000	0	0	0.0	1.8	1.004	16	1.000	0	0	0.0
	2.1	14	2.2	1.006	14	1.000	0	0	0.0	2.1	1.000	14	1.000	0	0	0.0
egout	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
eil33-2	97.9	653	96.6	0.987	653	1.000	0	0	0.0	96.3	0.984	653	1.000	0	0	0.0
	83.8	665	83.9	1.001	665	1.000	0	0	0.0	83.9	1.001	665	1.000	0	0	0.0
	94.1	677	93.5	0.994	677	1.000	0	0	0.0	93.5	0.994	677	1.000	0	0	0.0
	101.1	629	103.2	1.021	629	1.000	0	0	0.0	100.9	0.998	629	1.000	0	0	0.0
eilB101	477.1	10286	597.9	*1.253*	13787	*1.337*	0	0	31.0	606.2	*1.270*	13787	*1.337*	0	0	64.0
	517.2	9113	555.0	*1.073*	10965	*1.201*	0	71	75.5	674.2	*1.303*	14104	*1.542*	0	7	97.3
	464.2	10337	491.5	*1.059*	10774	1.042	0	14	44.5	572.6	*1.233*	13036	*1.259*	0	0	36.5
	473.5	10139	649.7	*1.371*	15515	*1.525*	0	38	57.0	609.9	*1.288*	14496	*1.426*	0	27	140.0
enigma	0.5	215	0.5	1.000	215	1.000	0	0	0.0	0.5	1.000	215	1.000	0	0	0.0
	0.5	620	0.5	1.000	580	**0.944**	0	0	21.0	0.5	1.000	461	**0.779**	0	5	23.0
	0.5	863	0.5	1.007	946	*1.086*	0	3	18.0	0.7	*1.078*	1379	*1.536*	0	3	18.0
	0.8	1443	0.8	1.006	1485	1.027	0	0	26.5	0.7	0.972	1485	1.027	0	0	25.5
enlight13	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
enlight14	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
ex9	39.6	1	39.8	1.006	1	1.000	0	0	0.0	40.6	1.026	1	1.000	0	0	0.0
	39.5	1	38.6	0.979	1	1.000	0	0	0.0	38.7	0.981	1	1.000	0	0	0.0
	39.7	1	41.1	1.034	1	1.000	0	0	0.0	39.6	0.998	1	1.000	0	0	0.0
	38.3	1	38.3	1.001	1	1.000	0	0	0.0	38.0	0.993	1	1.000	0	0	0.0
fast0507	406.8	1268	353.3	**0.869**	1067	**0.853**	0	4	228.1	343.3	**0.844**	1066	**0.852**	0	2	211.5
	233.0	686	223.1	0.958	667	0.976	0	1	163.3	280.6	*1.203*	817	*1.167*	0	0	216.0
	249.7	803	213.1	**0.854**	737	**0.927**	0	1	143.0	280.9	*1.125*	985	*1.202*	0	0	223.6

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Table D.2: Computational results on MMMC: Conflict Diving

Instance	nolockdiving		coefdiving							confdiving						
	T	**N**	**T**	$\mathbf{T_Q}$	**N**	$\mathbf{N_Q}$	**F**	**C**	$\mathbf{D_\emptyset}$	**T**	$\mathbf{T_Q}$	**N**	$\mathbf{N_Q}$	**F**	**C**	$\mathbf{D_\emptyset}$
	247.1	859	253.2	1.024	930	*1.074*	0	3	211.5	238.5	0.965	840	0.980	0	0	211.0
fiball	5889.6	5972	4115.7	**0.699**	4050	**0.683**	0	22	385.0	5898.8	1.002	6057	1.014	0	26	366.4
	2923.8	3006	limit	*2.462*	7911	*2.579*	0	36	192.4	limit	*2.462*	7953	*2.593*	0	45	161.5
	2771.3	2859	5454.2	*1.968*	5996	*2.060*	0	48	358.8	limit	*2.597*	7626	*2.611*	0	123	203.5
	limit	8417	3375.2	**0.469**	3686	**0.445**	0	25	273.0	limit	1.000	7241	**0.862**	0	88	163.5
fiber	2.9	5	3.4	*1.114*	5	1.000	0	0	0.0	2.9	1.000	5	1.000	0	0	0.0
	2.6	4	2.6	1.008	4	1.000	0	0	0.0	2.6	1.003	4	1.000	0	0	0.0
	2.8	4	2.8	1.005	4	1.000	0	0	0.0	2.8	0.995	4	1.000	0	0	0.0
	2.8	6	2.8	1.000	6	1.000	0	0	0.0	2.8	0.997	6	1.000	0	0	0.0
fixnet6	6.0	3	6.4	*1.058*	3	1.000	0	0	0.0	6.0	1.001	3	1.000	0	0	0.0
	7.6	4	7.5	0.988	4	1.000	0	0	0.0	7.6	0.994	4	1.000	0	0	0.0
	8.2	4	8.2	0.992	4	1.000	0	0	0.0	8.3	1.012	4	1.000	0	0	0.0
	6.2	2	6.2	1.000	3	1.010	0	0	0.0	6.2	1.006	3	1.010	0	0	0.0
flugpl	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
gen	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
germanrr	limit	3720	limit	1.000	9378	*2.481*	0	54	87.2	limit	1.000	11139	*2.942*	0	9	205.6
	limit	6208	limit	1.000	4402	**0.714**	0	42	97.8	limit	1.000	2325	**0.384**	0	0	226.7
	limit	2261	limit	1.000	7370	*3.164*	0	60	92.4	limit	1.000	3232	*1.411*	0	32	247.9
	limit	2654	limit	1.000	2576	0.972	0	47	73.4	limit	1.000	3140	*1.176*	0	5	223.9
gesa2-o	0.9	4	0.9	0.985	4	1.000	0	0	0.0	1.1	*1.097*	4	1.000	0	0	0.0
	1.2	2	1.3	1.013	2	1.000	0	0	0.0	1.2	1.000	2	1.000	0	0	0.0
	0.7	2	0.7	1.012	2	1.000	0	0	0.0	0.7	1.012	2	1.000	0	0	0.0
	0.9	2	0.9	0.995	2	1.000	0	0	0.0	0.8	0.989	2	1.000	0	0	0.0
gesa2	0.8	2	0.6	**0.910**	2	1.000	0	0	0.0	1.1	*1.152*	2	1.000	0	0	0.0
	0.6	2	0.6	1.006	2	1.000	0	0	0.0	0.6	1.000	2	1.000	0	0	0.0
	0.6	2	0.6	1.012	2	1.000	0	0	0.0	0.6	1.000	2	1.000	0	0	0.0
	0.6	2	0.6	1.000	2	1.000	0	0	0.0	0.6	0.988	2	1.000	0	0	0.0
gesa3	9.2	10	8.8	0.962	10	1.000	0	0	0.0	9.0	0.983	10	1.000	0	0	0.0
	6.6	5	7.8	*1.160*	6	1.010	0	0	0.0	7.7	*1.152*	6	1.010	0	0	0.0
	7.0	7	7.1	1.006	7	1.000	0	0	0.0	7.1	1.006	7	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: CONFLICT DIVING

Instance	nolockdiving		coefdiving							confdiving						
	T	**N**	**T**	**TQ**	**N**	**NQ**	**F**	**C**	**D∅**	**T**	**TQ**	**N**	**NQ**	**F**	**C**	**D∅**
	6.6	6	6.6	1.001	6	1.000	0	0	0.0	6.5	0.995	6	1.000	0	0	0.0
gesa3_o	3.0	6	2.7	**0.932**	6	1.000	0	0	0.0	2.8	**0.942**	6	1.000	0	0	0.0
	2.9	8	2.9	1.000	8	1.000	0	0	0.0	2.9	0.997	8	1.000	0	0	0.0
	3.7	7	3.7	0.998	7	1.000	0	0	0.0	3.7	1.000	7	1.000	0	0	0.0
	2.9	6	2.9	1.000	6	1.000	0	0	0.0	2.9	0.987	6	1.000	0	0	0.0
glass4	2038.7	1234030	1505.5	**0.739**	768818	**0.623**	0	177	62.6	1082.5	**0.531**	597949	**0.485**	0	345	50.7
	limit	4944800	1645.2	**0.229**	1199730	**0.243**	0	382	59.2	4455.5	**0.619**	2757727	**0.558**	2	2115	50.0
	2203.8	1489727	948.9	**0.431**	750382	**0.504**	1	368	60.5	1106.3	**0.502**	848383	**0.570**	1	1064	51.5
gmu-35-40	limit	4129349	limit	1.000	3530225	**0.855**	0	30	52.6	limit	1.000	3505480	**0.849**	0	18	43.9
	limit	2881135	limit	1.000	4747242	*1.648*	0	0	49.5	limit	1.000	4252946	*1.476*	0	10	41.5
	limit	4735500	limit	1.000	4544172	0.960	0	0	56.4	limit	1.000	3276994	**0.692**	0	26	44.2
	limit	5006940	limit	1.000	3589279	**0.717**	0	0	52.3	limit	1.000	3295917	**0.658**	1	17	46.5
gt2	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
haprp	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
iis-100-0-cov	826.6	106529	802.7	0.971	103091	0.968	0	75	21.4	803.8	0.972	102235	0.960	0	91	22.7
	722.6	92803	720.8	0.998	92475	0.996	0	85	20.9	731.7	1.013	94037	1.013	0	93	23.8
	645.1	80389	652.0	1.011	81601	1.015	0	71	23.1	654.4	1.014	81509	1.014	0	80	23.2
	717.3	90721	692.9	0.966	86709	0.956	0	111	24.4	734.5	1.024	93707	1.033	0	96	22.8
iis-bupa-cov	2339.8	150128	2393.2	1.023	156016	1.039	0	192	46.1	2535.1	*1.083*	166890	*1.112*	0	164	45.9
	2348.4	153532	2438.5	1.038	160860	1.048	0	365	45.7	2513.4	*1.070*	154710	1.008	0	73	50.2
	2485.2	163655	2682.1	*1.079*	187396	*1.145*	0	258	45.8	2455.6	0.988	164401	1.005	0	202	46.4
	2472.3	160525	2370.4	0.959	157506	0.981	0	178	46.3	2394.1	0.968	152397	**0.949**	0	252	45.6
iis-pima-cov	499.6	9512	498.4	0.997	9246	0.972	0	11	77.1	510.8	1.022	9330	0.981	0	17	81.1
	498.8	9925	499.2	1.001	10062	1.014	0	18	80.6	422.5	**0.847**	6641	**0.672**	0	7	77.8
	335.6	5064	372.1	*1.108*	6479	*1.274*	0	7	75.2	348.9	1.039	5829	*1.148*	0	3	80.8
	446.8	6877	669.6	*1.498*	15737	*2.270*	0	12	76.3	421.9	**0.944**	7115	1.034	0	8	81.0
khb05250	0.7	2	0.7	1.018	2	1.000	0	0	0.0	0.8	*1.085*	2	1.000	0	0	0.0
	0.5	2	0.5	1.000	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0
	0.5	2	0.5	1.000	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	0.5	2	0.5	0.987	2	1.000	0	0	0.0	0.5	0.993	2	1.000	0	0	0.0
l152lav	3.0	30	3.3	*1.088*	33	1.023	0	0	0.0	3.1	1.025	33	1.023	0	0	0.0
	3.0	43	3.0	1.000	43	1.000	0	0	0.0	2.9	0.990	43	1.000	0	0	0.0
	3.0	39	3.0	1.002	39	1.000	0	0	0.0	3.0	0.988	39	1.000	0	0	0.0
	2.5	32	2.6	1.029	30	0.985	0	0	32.0	2.4	0.977	34	1.015	0	5	16.0
lectsched-4-obj	54.6	2296	42.4	**0.780**	1104	**0.503**	1	12	90.7	33.5	**0.620**	501	**0.251**	0	6	131.0
	158.2	4137	82.2	**0.523**	857	**0.226**	2	174	102.9	140.6	**0.889**	1714	**0.428**	2	192	86.8
	12.0	5	12.1	1.004	5	1.000	0	0	0.0	12.0	1.002	5	1.000	0	0	0.0
	12.9	5	52.4	*3.833*	2136	*21.295*	0	75	91.1	12.8	0.989	5	1.000	0	0	0.0
leo1	limit	61193	limit	1.000	85707	*1.400*	0	3	90.0	limit	1.000	52607	**0.860**	0	0	30.5
	limit	58114	limit	1.000	52305	**0.900**	0	0	138.0	limit	1.000	60950	1.049	0	2	103.2
	limit	82444	limit	1.000	88974	*1.079*	0	4	108.3	limit	1.000	76399	**0.927**	0	0	128.3
	limit	80955	limit	1.000	107895	*1.332*	0	0	80.0	limit	1.000	50943	**0.630**	0	0	66.2
leo2	limit	78564	limit	1.000	88973	*1.132*	0	0	0.0	limit	1.000	78989	1.005	0	0	0.0
	limit	83637	limit	1.000	86751	1.037	0	0	0.0	limit	1.000	86277	1.032	0	0	0.0
	limit	80728	limit	1.000	78861	0.977	0	0	0.0	limit	1.000	81464	1.009	0	0	0.0
	limit	67978	limit	1.000	74735	*1.099*	0	0	0.0	limit	1.000	68047	1.001	0	0	0.0
liu	limit	1285212	limit	1.000	1610188	*1.253*	4	107	298.4	limit	1.000	1634858	*1.272*	6	79	299.9
	limit	1917526	limit	1.000	1634197	**0.852**	0	71	290.5	limit	1.000	1616663	**0.843**	4	170	303.1
	limit	1541049	limit	1.000	1660341	*1.077*	7	171	306.3	limit	1.000	1324806	**0.860**	0	41	294.3
	limit	1418829	limit	1.000	1460707	1.030	12	169	296.3	limit	1.000	1418024	0.999	15	178	294.4
lrn	limit	3345	limit	1.000	2375	**0.718**	1	3	81.7	limit	1.000	3955	*1.177*	0	1	89.6
	limit	2502	limit	1.000	2505	1.001	0	13	72.3	limit	1.000	2907	*1.156*	0	0	74.0
	limit	1990	limit	1.000	2212	*1.106*	0	14	73.8	limit	1.000	3685	*1.811*	0	5	84.4
	limit	2880	limit	1.000	3184	*1.102*	0	20	68.4	limit	1.000	3902	*1.343*	1	10	109.0
lseu	1.0	176	1.2	*1.103*	176	1.000	0	0	0.0	1.3	*1.118*	176	1.000	0	0	0.0
	0.5	4	0.5	1.000	4	1.000	0	0	0.0	0.5	1.000	4	1.000	0	0	0.0
	0.5	70	0.5	1.007	68	0.988	0	0	0.0	0.5	1.007	70	1.000	0	0	0.0
	0.8	264	0.8	1.028	275	1.030	0	0	15.0	0.9	1.039	264	1.000	0	0	0.0
m100n500k4r1	limit	3729849	limit	1.000	4137930	*1.109*	0	16	35.7	limit	1.000	3328422	**0.892**	0	4	84.0
	limit	3552461	limit	1.000	3638211	1.024	0	20	46.5	limit	1.000	3552222	1.000	0	13	34.8
	limit	3736953	limit	1.000	3609052	0.966	0	0	48.2	limit	1.000	3617264	0.968	0	18	46.1
	limit	3838400	limit	1.000	3676155	0.958	0	12	52.0	limit	1.000	4033988	*1.051*	0	0	54.5
macrophage	159.1	5108	161.6	1.016	5034	0.986	0	4	171.0	154.4	0.971	5005	0.980	0	11	183.7
	172.6	5046	202.8	*1.174*	6177	*1.220*	0	5	157.5	170.6	0.988	5410	*1.071*	0	2	168.0
	228.6	8063	187.5	**0.821**	6176	**0.769**	0	63	149.1	204.3	**0.894**	6861	**0.853**	0	23	243.4

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Table D.2: Computational results on MMMC: CONFLICT DIVING

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	149.5	4564	162.9	*1.089*	5602	*1.223*	0	8	149.1	163.1	*1.091*	6085	*1.326*	0	13	162.5
manna81	0.8	1	0.8	0.962	1	1.000	0	0	0.0	0.8	0.989	1	1.000	0	0	0.0
	0.6	1	0.6	0.975	1	1.000	0	0	0.0	0.6	0.994	1	1.000	0	0	0.0
	0.6	1	0.6	0.987	1	1.000	0	0	0.0	0.6	1.038	1	1.000	0	0	0.0
	0.6	1	0.6	1.019	1	1.000	0	0	0.0	0.6	1.026	1	1.000	0	0	0.0
map18	353.5	239	301.2	**0.853**	249	1.029	0	8	34.0	323.9	**0.917**	239	1.000	0	3	20.0
	253.7	255	353.9	*1.393*	273	*1.051*	0	1	22.0	289.9	*1.142*	263	1.023	0	0	28.0
	364.8	300	305.1	**0.837**	305	1.012	0	4	35.0	350.7	0.961	317	1.042	0	5	14.0
	370.1	255	310.3	**0.839**	231	**0.932**	0	7	35.0	284.8	**0.770**	257	1.006	0	3	11.0
map20	331.7	245	239.8	**0.724**	392	*1.426*	0	1	29.0	326.7	0.985	231	0.959	0	2	16.0
	316.5	219	318.0	1.005	237	*1.056*	0	6	37.5	322.2	1.018	213	0.981	0	6	15.0
	201.1	233	282.1	*1.401*	406	*1.520*	0	2	31.0	200.4	0.997	235	1.006	0	2	15.0
	273.6	229	278.9	1.019	247	*1.055*	0	4	37.0	241.6	**0.883**	223	0.982	0	2	14.0
markshare1	limit	34394997	limit	1.000	33973218	0.988	3	15	33.7	limit	1.000	32020324	**0.931**	0	12	33.8
	limit	34291418	limit	1.000	32839202	0.958	3	20	33.8	limit	1.000	32964973	0.961	1	11	34.1
	limit	32587792	limit	1.000	33087280	1.015	3	26	33.7	limit	1.000	33658434	1.033	0	16	33.0
	limit	33689076	limit	1.000	35371651	1.050	4	13	33.6	limit	1.000	33035891	0.981	1	25	33.9
markshare2	limit	13790121	limit	1.000	13461681	0.976	2	19	40.2	limit	1.000	14242961	1.033	1	20	39.0
	limit	15279315	limit	1.000	14370971	**0.941**	1	13	40.5	limit	1.000	14611841	0.956	0	8	40.1
	limit	13888399	limit	1.000	13491300	0.971	2	23	39.8	limit	1.000	14392598	1.036	1	24	38.8
	limit	14323408	limit	1.000	14420415	1.007	2	28	40.1	limit	1.000	13525381	**0.944**	1	24	39.0
mas74	1629.3	5182414	2004.9	*1.230*	6027541	*1.163*	0	116	26.4	1850.6	*1.136*	5686594	*1.097*	0	42	29.6
	2728.8	6183035	2714.7	0.995	6950287	*1.124*	0	92	26.9	1685.2	**0.618**	5711243	**0.924**	0	46	30.3
	1952.1	5906746	2381.2	*1.220*	7071228	*1.197*	0	95	27.4	1898.8	0.973	5844232	0.989	0	48	29.7
mas76	124.3	261470	94.9	**0.765**	198417	**0.759**	0	396	19.4	111.6	**0.898**	219476	**0.839**	0	260	21.1
	101.7	201143	153.5	*1.505*	360101	*1.790*	0	370	19.6	199.1	*1.948*	556219	*2.764*	0	381	20.3
	106.7	200421	114.2	*1.070*	246746	*1.231*	0	417	19.2	124.2	*1.163*	265676	*1.325*	0	601	19.3
	168.3	463174	112.5	**0.671**	209149	**0.452**	0	502	20.4	175.4	1.042	500161	*1.080*	0	334	21.1
mcsched	261.2	8906	241.5	**0.925**	7120	**0.802**	0	53	17.2	244.7	**0.937**	7751	**0.872**	0	26	100.9
	275.0	8523	266.4	0.969	8226	0.966	0	20	15.5	271.5	0.987	8902	1.044	0	22	94.7
	346.2	11394	373.9	*1.080*	13747	*1.205*	0	54	17.0	383.9	*1.109*	14875	*1.303*	0	34	86.7
	206.7	6037	209.7	1.014	6145	1.018	0	23	17.6	205.7	0.995	5956	0.987	0	9	108.1
mik-250-1-100-1	86.4	22390	87.3	1.010	22968	1.026	0	83	48.2	69.6	**0.807**	19057	**0.852**	0	68	59.1
	73.0	22060	51.5	**0.710**	15147	**0.688**	0	21	48.1	98.5	*1.344*	27644	*1.252*	0	52	57.3
	76.7	20383	89.3	*1.162*	23266	*1.141*	0	95	48.5	68.9	**0.900**	16878	**0.829**	1	141	58.1

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving							
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	112.0	27190	135.1	*1.205*	34844	*1.280*	0	38	50.6	109.7	0.980	27408	1.008	0	74	48.8
mine-166-5	78.5	12	82.5	*1.050*	276	*3.357*	0	0	0.0	78.9	1.005	131	*2.062*	0	0	0.0
	82.4	2002	90.3	*1.095*	2802	*1.381*	0	38	38.5	85.3	1.036	1848	**0.927**	0	22	33.0
	59.0	1333	63.1	*1.069*	2538	*1.841*	1	81	54.0	58.5	0.991	1169	**0.886**	0	26	51.0
	64.1	1228	65.9	1.028	1615	*1.291*	1	0	37.0	68.7	*1.071*	2352	*1.846*	0	5	35.0
mine-90-10	412.8	32102	536.6	*1.299*	38513	*1.199*	0	1066	62.8	334.4	**0.811**	31547	0.983	0	2579	48.9
	290.0	35136	245.4	**0.847**	25651	**0.731**	1	764	52.4	460.0	*1.584*	43443	*1.236*	0	2198	60.3
	346.9	33747	467.3	*1.346*	47767	*1.414*	1	711	55.8	461.1	*1.328*	40478	*1.199*	0	1827	44.1
	353.5	31760	940.5	*2.656*	76187	*2.394*	1	2550	58.1	558.0	*1.577*	50369	*1.584*	0	3179	50.0
misc03	1.1	11	0.6	**0.770**	11	1.000	0	0	0.0	1.1	0.995	11	1.000	0	0	0.0
	1.0	23	1.0	1.005	23	1.000	0	0	0.0	1.1	1.025	23	1.000	0	0	0.0
	0.6	7	0.5	0.987	7	1.000	0	0	0.0	0.6	1.006	7	1.000	0	0	0.0
	0.8	29	0.8	1.000	29	1.000	0	0	0.0	0.8	1.011	29	1.000	0	0	0.0
misc06	1.0	3	0.7	**0.840**	3	1.000	0	0	0.0	1.2	*1.095*	3	1.000	0	0	0.0
	0.8	3	0.8	0.994	3	1.000	0	0	0.0	0.8	1.006	3	1.000	0	0	0.0
	0.6	3	0.6	1.019	3	1.000	0	0	0.0	0.6	0.994	3	1.000	0	0	0.0
	0.5	3	0.6	1.039	3	1.000	0	0	0.0	0.6	1.045	3	1.000	0	0	0.0
misc07	13.1	6038	13.3	1.018	6065	1.004	0	166	28.6	13.3	1.017	5971	0.989	0	82	31.1
	14.9	6123	15.0	1.009	6097	0.996	0	90	26.3	14.8	0.994	6084	0.994	0	79	34.5
	15.9	7464	15.9	0.999	7615	1.020	0	179	27.1	15.9	0.998	7553	1.012	0	157	26.6
	11.6	5102	11.4	0.980	5035	0.987	0	35	19.5	11.6	1.000	5102	1.000	0	42	28.6
mitre	12.0	1	12.1	1.006	1	1.000	0	0	0.0	12.2	1.017	1	1.000	0	0	0.0
	12.2	1	12.0	0.989	1	1.000	0	0	0.0	12.1	0.994	1	1.000	0	0	0.0
	12.2	1	12.1	0.994	1	1.000	0	0	0.0	12.2	1.002	1	1.000	0	0	0.0
	15.5	1	15.5	0.999	1	1.000	0	0	0.0	15.4	0.993	1	1.000	0	0	0.0
mkc1	5695.1	1704770	3438.2	**0.604**	951305	**0.558**	0	3	42.3	limit	*1.264*	1965655	*1.153*	0	86	88.1
	167.8	15636	limit	*42.652*	1703742	*108.277*	0	23	49.8	88.1	**0.528**	5444	**0.352**	0	14	44.7
	36.1	1431	109.8	*2.986*	12288	*8.091*	0	1	24.0	54.6	*1.498*	2990	*2.018*	0	1	64.0
	limit	2071458	limit	1.000	2101693	1.015	0	33	78.5	6126.8	**0.851**	1853553	**0.895**	0	35	70.3
mkc	limit	434115	limit	1.000	613580	*1.413*	0	61	90.9	limit	1.000	378715	**0.872**	0	172	156.8
	limit	364203	limit	1.000	508660	*1.397*	0	187	95.6	limit	1.000	406920	*1.117*	0	54	166.4
	limit	456507	limit	1.000	498346	*1.092*	1	345	98.1	limit	1.000	447731	0.981	0	21	158.4
	limit	365047	limit	1.000	608098	*1.666*	0	310	97.8	limit	1.000	408389	*1.119*	0	119	167.7
mod008	1.2	1	1.2	1.000	1	1.000	0	0	0.0	1.2	0.991	1	1.000	0	0	0.0
	1.2	1	1.2	1.004	1	1.000	0	0	0.0	1.3	1.009	1	1.000	0	0	0.0
	1.3	1	1.3	1.018	1	1.000	0	0	0.0	1.3	1.004	1	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: CONFLICT DIVING

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	1.2	1	1.2	0.995	1	1.000	0	0	0.0	1.1	0.991	1	1.000	0	0	0.0
mod010	0.5	2	0.5	1.020	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0
	0.6	2	0.6	0.994	2	1.000	0	0	0.0	0.6	1.045	2	1.000	0	0	0.0
	0.5	2	0.5	1.007	2	1.000	0	0	0.0	0.5	0.987	2	1.000	0	0	0.0
	0.8	2	0.8	0.989	2	1.000	0	0	0.0	0.8	1.005	2	1.000	0	0	0.0
mod011	465.9	619	404.6	**0.869**	586	0.954	0	0	63.3	459.0	0.985	619	1.000	0	0	0.0
	667.9	661	616.0	**0.922**	683	1.029	0	0	36.4	671.8	1.006	661	1.000	0	0	0.0
	197.0	1136	200.3	1.017	1353	*1.176*	1	0	32.1	193.9	0.984	1136	1.000	0	0	0.0
	366.3	647	384.9	*1.051*	696	*1.066*	0	0	51.4	365.5	0.998	647	1.000	0	0	0.0
modglob	0.6	2	0.6	0.988	2	1.000	0	0	0.0	0.6	1.000	2	1.000	0	0	0.0
	0.5	2	0.5	1.000	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0
	0.5	2	0.5	1.000	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0
momentum1	limit	10878	limit	1.000	32726	*2.990*	0	0	89.2	limit	1.000	22201	*2.031*	0	0	46.3
	limit	37872	limit	1.000	51213	*1.351*	0	39	54.9	limit	1.000	86613	*2.284*	0	2	39.6
	limit	18088	limit	1.000	18136	1.003	0	3	72.5	limit	1.000	28862	*1.592*	0	31	36.1
	limit	85587	limit	1.000	12387	**0.146**	0	52	52.9	limit	1.000	36856	**0.431**	0	60	43.4
momentum3	limit	217	limit	1.000	195	**0.931**	1	84	769.5	limit	1.000	131	**0.729**	0	0	147.0
	limit	370	limit	1.000	449	*1.168*	2	139	457.2	limit	1.000	186	**0.609**	0	7	89.0
	limit	294	limit	1.000	281	0.967	0	59	332.3	limit	1.000	234	**0.848**	0	0	327.0
	limit	286	limit	1.000	1104	*3.119*	0	124	397.7	limit	1.000	1178	*3.311*	0	180	292.1
msc98-ip	limit	4385	limit	1.000	4373	0.997	0	1847	84.7	limit	1.000	6869	*1.554*	0	1199	90.4
	limit	4452	limit	1.000	3593	**0.811**	0	886	80.9	limit	1.000	3727	**0.841**	0	1334	44.5
	limit	5053	limit	1.000	4995	0.989	0	1166	85.3	limit	1.000	12282	*2.403*	0	2008	55.0
	limit	3524	limit	1.000	6482	*1.816*	0	437	74.1	limit	1.000	3716	*1.053*	0	1612	37.7
mspp16	460.5	3	461.1	1.001	3	1.000	0	0	0.0	458.9	0.997	3	1.000	0	0	0.0
	463.5	5	457.6	0.987	5	1.000	0	0	0.0	458.2	0.989	5	1.000	0	0	0.0
	446.9	5	441.7	0.988	5	1.000	0	0	0.0	440.7	0.986	5	1.000	0	0	0.0
	416.6	5	413.7	0.993	5	1.000	0	0	0.0	414.8	0.996	5	1.000	0	0	0.0
mzzv11	310.1	2020	369.8	*1.192*	2672	*1.308*	0	10	47.0	371.0	*1.196*	2540	*1.245*	0	29	38.0
	252.6	833	450.2	*1.779*	2212	*2.478*	0	7	127.7	307.8	*1.218*	1007	*1.186*	0	18	166.0
	401.2	2039	406.6	1.013	2189	*1.070*	0	0	187.0	485.6	*1.210*	3120	*1.505*	0	60	80.8
	343.1	1629	362.4	*1.056*	1922	*1.169*	0	11	36.2	260.2	**0.759**	968	**0.618**	0	6	81.3
mzzv42z	200.8	319	157.2	**0.784**	174	**0.654**	0	1	74.0	232.8	*1.159*	387	*1.162*	1	8	49.0
	202.5	283	207.5	1.024	309	*1.068*	0	2	27.0	183.3	**0.905**	236	**0.877**	0	10	34.0
	186.4	214	188.2	1.010	214	1.000	0	4	60.0	186.3	0.999	214	1.000	0	8	87.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	169.6	136	224.1	*1.319*	514	*2.602*	1	0	33.0	197.2	*1.162*	204	*1.288*	0	4	23.0
n3div36	limit	167851	limit	1.000	165867	0.988	0	7	107.0	limit	1.000	164205	0.978	0	12	126.4
	limit	170420	limit	1.000	168468	0.989	0	2	111.1	limit	1.000	168094	0.986	0	4	78.0
	limit	169332	limit	1.000	177416	1.048	0	1	128.0	limit	1.000	179559	*1.060*	0	19	115.7
	limit	166614	limit	1.000	161986	0.972	0	7	113.0	limit	1.000	165397	0.993	0	5	120.5
n3seq24	limit	274	limit	1.000	257	0.955	0	0	396.3	limit	1.000	307	*1.088*	0	0	112.0
	limit	795	limit	1.000	1472	*1.756*	0	0	254.2	limit	1.000	1393	*1.668*	0	0	63.8
	limit	650	limit	1.000	363	**0.617**	0	0	351.7	limit	1.000	538	**0.851**	0	0	74.2
	limit	279	limit	1.000	1313	*3.728*	1	0	192.9	limit	1.000	673	*2.040*	0	0	78.9
n4-3	230.6	2733	227.3	0.986	2929	*1.069*	9	49	32.4	258.1	*1.119*	3349	*1.217*	10	41	29.2
	245.6	2239	289.1	*1.177*	2886	*1.277*	8	40	40.1	223.0	**0.908**	1945	**0.874**	8	28	33.4
	247.6	2467	241.0	0.974	2706	*1.093*	10	19	32.8	302.6	*1.221*	3717	*1.487*	10	48	46.7
	280.5	3101	266.0	**0.949**	3225	1.039	14	26	34.7	216.2	**0.771**	2374	**0.773**	2	24	31.7
nag	limit	48570	limit	1.000	48829	1.005	0	99	115.9	limit	1.000	146194	*3.006*	0	316	93.7
	limit	74420	limit	1.000	55849	**0.751**	0	77	132.5	limit	1.000	89041	*1.196*	0	149	83.3
	limit	105272	limit	1.000	99246	**0.943**	0	66	85.1	limit	1.000	138843	*1.319*	1	257	78.8
	limit	31182	limit	1.000	23427	**0.752**	0	103	111.8	limit	1.000	51567	*1.652*	0	100	109.4
neos-1053234	4265.2	645570	limit	*1.688*	1058036	*1.639*	0	19	60.7	1376.9	**0.323**	660701	1.023	0	25	32.0
	4338.0	1047806	3184.5	**0.734**	1208017	*1.153*	0	23	57.3	441.6	**0.102**	119766	**0.114**	0	15	33.3
	952.6	66600	2190.9	*2.298*	377762	*5.665*	0	4	63.0	1606.0	*1.685*	305277	*4.578*	0	34	32.1
	limit	1179819	limit	1.000	437738	**0.371**	0	8	59.2	4402.5	**0.612**	1155822	0.980	0	171	45.7
neos-1053591	6.5	2800	5.6	**0.878**	2493	**0.894**	1	6	14.5	6.9	*1.055*	3626	*1.285*	0	3	15.0
	6.8	5404	3.4	**0.567**	1568	**0.303**	0	8	16.0	4.2	**0.665**	2824	**0.531**	0	3	18.7
	3.1	1208	3.2	1.030	1364	*1.119*	0	7	19.0	3.6	*1.140*	1559	*1.268*	0	4	16.3
	21.1	17022	23.6	*1.113*	19713	*1.157*	0	75	25.8	22.2	1.049	16891	0.992	0	60	26.8
neos-1056905	limit	13652151	limit	1.000	11244197	**0.824**	0	840	106.5	limit	1.000	7318375	**0.536**	0	2796	79.4
	limit	12271513	limit	1.000	5416542	**0.441**	0	2051	75.2	4168.5	**0.579**	2915687	**0.238**	0	2577	69.6
	limit	14313346	limit	1.000	12919505	**0.903**	0	342	82.9	limit	1.000	15101004	*1.055*	0	2974	79.9
	limit	15601603	limit	1.000	9340429	**0.599**	0	969	63.4	limit	1.000	12408534	**0.795**	0	456	72.3
neos-1058477	0.6	1	0.9	*1.197*	1	1.000	0	0	0.0	0.6	1.000	1	1.000	0	0	0.0
	0.6	1	0.6	0.994	1	1.000	0	0	0.0	0.6	1.019	1	1.000	0	0	0.0
	1.0	1	1.0	1.000	1	1.000	0	0	0.0	1.0	1.010	1	1.000	0	0	0.0
	0.6	1	0.7	*1.069*	1	1.000	0	0	0.0	0.6	1.000	1	1.000	0	0	0.0
neos-1061020	428.3	2130	374.4	**0.874**	1553	**0.741**	0	20	40.8	320.2	**0.748**	1179	**0.574**	0	3	120.0
	136.7	547	388.6	*2.831*	1265	*2.110*	0	15	60.2	310.6	*2.264*	1210	*2.025*	0	46	62.6
	168.9	484	272.5	*1.610*	841	*1.611*	0	39	247.5	5373.3	*31.631*	31152	*53.514*	0	135	101.3

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Table D.2: Computational results on MMMC: CONFLICT DIVING

Instance	nolockdiving		coefdiving							confdiving						
	T	**N**	**T**	**T_Q**	**N**	**N_Q**	**F**	**C**	**$D_\emptyset$**	**T**	**T_Q**	**N**	**N_Q**	**F**	**C**	**$D_\emptyset$**
	328.9	1485	230.7	**0.702**	857	**0.604**	0	2	284.3	341.4	1.038	1802	*1.200*	0	15	119.0
neos-1062641	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
neos-1067731	limit	200544	limit	1.000	196705	0.981	0	65	229.3	limit	1.000	176165	**0.878**	0	79	220.0
	limit	196399	limit	1.000	186253	**0.948**	0	61	209.1	limit	1.000	189997	0.967	0	64	173.7
	limit	196617	limit	1.000	208200	*1.059*	0	90	206.5	limit	1.000	142437	**0.725**	0	69	165.5
	limit	222043	limit	1.000	146151	**0.658**	0	48	222.9	limit	1.000	137743	**0.621**	0	45	205.7
neos-1096528	2267.5	3276	2228.9	0.983	3228	0.986	0	9	34.5	2166.6	0.956	3181	0.972	0	74	23.5
	1873.9	1052	1851.1	0.988	1052	1.000	0	0	0.0	1854.0	0.989	1052	1.000	0	0	0.0
	1629.1	1706	1630.7	1.001	1698	0.996	0	9	35.0	1629.2	1.000	1702	0.998	0	31	23.0
	2108.7	3610	2126.7	1.009	3715	1.028	0	19	55.3	2097.9	0.995	3621	1.003	0	45	28.0
neos-1109824	15.4	110	15.3	0.994	110	1.000	0	0	0.0	15.6	1.008	110	1.000	0	0	0.0
	18.5	114	18.5	1.001	114	1.000	0	0	0.0	18.5	1.000	114	1.000	0	0	0.0
	38.0	388	21.8	**0.584**	145	**0.502**	0	6	85.0	26.8	**0.713**	238	**0.693**	0	9	10.0
	14.9	64	14.8	0.996	64	1.000	0	0	0.0	15.1	1.014	64	1.000	0	0	0.0
neos-1120495	8.0	21	7.8	0.977	21	1.000	0	0	0.0	8.1	1.013	21	1.000	0	0	0.0
	6.3	8	6.3	1.004	8	1.000	0	0	0.0	6.2	0.993	8	1.000	0	0	0.0
	10.9	16	11.0	1.006	16	1.000	0	0	0.0	10.9	1.002	16	1.000	0	0	0.0
	6.3	3	6.2	0.988	3	1.000	0	0	0.0	6.2	0.988	3	1.000	0	0	0.0
neos-1121679	limit	34300440	limit	1.000	33391098	0.973	3	15	33.7	limit	1.000	30534646	**0.890**	0	12	33.8
	limit	33976691	limit	1.000	32954649	0.970	3	20	33.8	limit	1.000	32978643	0.971	1	11	34.1
	limit	32507153	limit	1.000	33037996	1.016	3	26	33.7	limit	1.000	33788327	1.039	0	16	33.0
	limit	33739808	limit	1.000	35358763	1.048	4	13	33.6	limit	1.000	34521648	1.023	1	25	33.9
neos-1122047	7.1	1	6.9	0.974	1	1.000	0	0	0.0	7.1	1.000	1	1.000	0	0	0.0
	7.0	1	6.6	0.959	1	1.000	0	0	0.0	7.1	1.018	1	1.000	0	0	0.0
	7.0	1	7.0	0.989	1	1.000	0	0	0.0	7.2	1.015	1	1.000	0	0	0.0
	7.2	1	6.9	0.972	1	1.000	0	0	0.0	7.0	0.977	1	1.000	0	0	0.0
neos-1126860	627.4	4187	605.3	0.965	4681	*1.115*	1	5	20.8	639.7	1.020	4171	0.996	1	58	19.2
	619.8	4406	593.0	0.957	4431	1.006	0	0	20.4	611.1	0.986	4610	1.045	0	17	17.2
	621.7	4401	612.1	0.985	4090	**0.931**	0	0	21.6	654.5	*1.053*	4396	0.999	1	58	20.3
	602.8	4417	619.1	1.027	4175	**0.946**	0	1	21.0	614.6	1.019	4420	1.001	0	26	16.5
neos-1151496	29.7	67	23.4	**0.795**	89	*1.132*	0	0	240.0	26.0	**0.880**	81	*1.084*	0	0	13.0
	21.7	64	21.6	0.996	64	1.000	0	0	0.0	21.6	0.997	64	1.000	0	0	0.0
	3.1	1	3.2	1.002	1	1.000	0	0	0.0	3.2	1.005	1	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	37.9	98	35.9	**0.948**	81	**0.914**	0	0	236.0	37.5	0.991	91	0.965	0	0	9.0
neos-1171448	10.4	1	11.2	*1.073*	1	1.000	0	0	0.0	10.4	1.002	1	1.000	0	0	0.0
	845.0	104	80.0	**0.096**	120	*1.078*	0	0	580.0	845.2	1.000	104	1.000	0	0	0.0
	11.7	1	11.0	**0.943**	1	1.000	0	0	0.0	11.7	0.998	1	1.000	0	0	0.0
	11.4	1	75.6	*6.156*	89	*1.871*	0	0	598.0	11.4	0.994	1	1.000	0	0	0.0
neos-1171692	593.8	256	37.5	**0.065**	241	0.958	0	0	199.0	648.0	*1.091*	256	1.000	0	0	114.0
	25.9	41	1009.4	*37.632*	271	*2.631*	0	1	274.0	25.7	0.995	41	1.000	0	0	0.0
	644.5	143	5.3	**0.010**	1	**0.416**	0	0	0.0	177.0	**0.276**	36	**0.560**	0	0	0.0
	1017.8	327	90.4	**0.090**	38	**0.323**	0	0	0.0	1237.5	*1.216*	385	*1.136*	0	0	178.0
neos-1171737	limit	3483	limit	1.000	3256	**0.937**	0	36	199.2	limit	1.000	3621	1.039	0	0	110.8
	limit	5773	limit	1.000	3809	**0.666**	0	51	263.0	limit	1.000	5849	1.013	0	93	138.3
	limit	4327	limit	1.000	3713	**0.861**	0	98	211.9	limit	1.000	8936	*2.041*	0	161	116.2
	limit	3592	limit	1.000	5451	*1.504*	0	81	252.2	limit	1.000	3947	*1.096*	0	41	102.8
neos-1173026	0.6	1	0.5	0.968	1	1.000	0	0	0.0	0.5	0.968	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
neos-1200887	15.3	7506	16.6	*1.079*	7621	1.015	0	17	33.2	17.3	*1.123*	7047	**0.940**	0	0	26.0
	10.4	3101	9.8	**0.946**	2934	**0.948**	0	16	36.2	11.4	*1.086*	3138	1.012	1	17	23.4
	25.8	11277	25.9	1.003	11880	*1.053*	0	26	33.3	27.6	*1.065*	11680	1.035	0	45	28.6
	12.6	3179	12.4	0.989	3646	*1.142*	0	0	32.2	11.2	**0.903**	3020	0.952	0	18	22.8
neos-1208069	94.6	1710	152.3	*1.603*	2294	*1.323*	0	633	73.4	76.6	**0.812**	1282	**0.764**	0	109	161.0
	56.7	1079	54.0	0.953	784	**0.750**	0	9	311.0	79.0	*1.386*	3291	*2.876*	0	1125	81.3
	86.7	3420	258.7	*2.961*	7099	*2.045*	0	229	201.4	122.5	*1.408*	4302	*1.251*	0	969	82.5
	103.6	2677	101.1	0.976	2881	*1.073*	0	657	121.4	83.2	**0.805**	2432	**0.912**	0	226	139.2
neos-1208135	183.7	4128	433.4	*2.352*	10513	*2.510*	0	199	233.2	195.4	*1.063*	2369	**0.584**	0	56	260.6
	209.4	7144	424.3	*2.022*	2838	**0.406**	0	149	293.0	192.4	**0.920**	1993	**0.289**	0	50	198.0
	469.5	6178	426.0	**0.908**	10535	*1.694*	0	0	228.2	239.9	**0.512**	3011	**0.496**	0	17	189.2
	351.1	6358	366.6	1.044	2554	**0.411**	0	91	180.2	84.4	**0.243**	665	**0.118**	0	21	238.3
neos-1211578	7.7	10541	7.5	0.979	10174	0.966	0	74	21.3	6.5	**0.872**	8858	**0.842**	0	81	19.6
	1.9	1371	2.1	*1.079*	1363	0.995	0	28	19.0	2.0	1.017	1353	0.988	0	11	19.8
	4.0	4482	4.7	*1.134*	5493	*1.221*	0	100	21.2	4.3	*1.070*	4651	1.037	0	42	19.6
	5.1	7154	5.6	*1.075*	7782	*1.087*	0	77	20.7	5.4	*1.052*	6991	0.978	0	36	20.3
neos-1215259	43.5	731	61.3	*1.399*	1123	*1.472*	0	153	118.3	53.4	*1.223*	883	*1.183*	0	27	46.8
	80.8	1522	69.8	**0.866**	1337	**0.886**	0	14	76.6	75.8	**0.939**	1186	**0.793**	0	100	38.7
	122.2	2871	71.9	**0.592**	1577	**0.564**	0	15	112.0	58.4	**0.482**	1488	**0.535**	0	43	31.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	74.9	1683	93.6	*1.246*	2353	*1.376*	0	154	51.3	78.7	1.049	1435	**0.861**	0	42	47.8
neos-1215891	815.2	7858	634.7	**0.779**	4997	**0.640**	0	23	414.5	756.2	**0.928**	8688	*1.104*	1	160	70.2
	557.4	3360	333.6	**0.599**	3221	0.960	0	12	471.0	526.2	**0.944**	3683	*1.093*	0	434	77.6
	454.3	2260	515.5	*1.134*	3240	*1.415*	0	16	458.8	509.9	*1.122*	3208	*1.402*	0	142	52.4
	334.1	2777	526.5	*1.574*	3148	*1.129*	0	22	378.5	634.0	*1.895*	5627	*1.991*	0	299	59.2
neos-1223462	158.7	35	178.6	*1.124*	67	*1.237*	0	0	523.0	158.7	1.000	56	*1.156*	0	0	524.0
	215.3	318	402.4	*1.865*	565	*1.591*	0	39	58.0	204.8	0.952	86	**0.445**	0	11	52.0
	168.6	155	171.9	1.019	155	1.000	0	0	0.0	170.1	1.008	155	1.000	0	0	0.0
	161.8	95	235.9	*1.455*	705	*4.128*	0	42	119.0	257.4	*1.587*	526	*3.210*	0	9	44.0
neos-1224597	24.9	21	24.9	1.001	21	1.000	0	0	0.0	24.7	0.993	21	1.000	0	0	0.0
	1.1	1	1.2	1.009	1	1.000	0	0	0.0	1.2	1.005	1	1.000	0	0	0.0
	62.1	102	61.9	0.996	102	1.000	0	0	0.0	62.1	1.000	102	1.000	0	0	0.0
	2.5	1	2.5	0.989	1	1.000	0	0	0.0	2.6	1.006	1	1.000	0	0	0.0
neos-1228986	12.1	17883	15.6	*1.267*	22116	*1.235*	0	383	23.3	15.2	*1.237*	23160	*1.293*	0	206	21.8
	33.2	65779	30.8	**0.928**	58746	**0.893**	0	416	24.6	25.5	**0.774**	43260	**0.658**	0	334	23.1
	53.6	127626	70.4	*1.307*	179182	*1.404*	0	1027	27.1	65.8	*1.224*	164399	*1.288*	0	945	24.7
	36.5	79395	24.3	**0.675**	48140	**0.607**	0	476	24.4	21.0	**0.587**	32793	**0.414**	0	231	22.4
neos-1281048	4.5	10	4.8	1.047	10	1.000	0	0	0.0	4.8	*1.064*	10	1.000	0	0	0.0
	10.9	162	10.9	1.003	162	1.000	0	0	0.0	10.9	1.001	162	1.000	0	0	0.0
	9.2	56	9.2	0.998	56	1.000	0	0	0.0	9.2	1.003	56	1.000	0	0	0.0
	6.6	28	6.6	1.003	28	1.000	0	0	0.0	6.6	1.003	28	1.000	0	0	0.0
neos-1311124	limit	11591653	limit	1.000	11203516	0.967	0	10654	81.9	limit	1.000	11106201	0.958	0	10500	77.8
	limit	10124593	limit	1.000	11496954	*1.136*	0	3025	76.7	limit	1.000	10473413	1.034	0	8104	75.7
	limit	10081351	limit	1.000	11180459	*1.109*	0	5803	82.3	limit	1.000	10963895	*1.088*	0	5327	76.0
	limit	10687235	limit	1.000	11214017	1.049	0	5214	77.1	limit	1.000	11975561	*1.121*	0	3332	76.1
neos-1324574	3397.4	26704	2607.7	**0.768**	16740	**0.628**	0	51	576.4	991.0	**0.292**	6301	**0.239**	0	169	42.6
	3077.0	23757	2740.5	**0.891**	21201	**0.893**	0	62	550.1	2962.3	0.963	26844	*1.129*	0	245	52.1
	333.5	2413	219.2	**0.658**	1212	**0.522**	0	10	486.5	230.2	**0.691**	1173	**0.507**	0	39	23.0
	1691.1	13365	1781.5	*1.053*	12780	0.957	0	19	468.3	791.0	**0.468**	5789	**0.437**	0	54	41.1
neos-1330346	limit	241496	4998.7	**0.694**	212094	**0.878**	0	4718	313.0	4615.9	**0.641**	211068	**0.874**	0	1782	79.9
	limit	228497	5874.8	**0.816**	241604	*1.057*	0	7163	312.4	4642.9	**0.645**	185844	**0.813**	0	12664	82.1
	4985.4	206094	limit	*1.444*	267956	*1.300*	0	822	309.0	3598.8	**0.722**	177559	**0.862**	0	8273	60.3
	6586.1	210422	5543.4	**0.842**	228558	*1.086*	0	4314	314.5	4299.5	**0.653**	230499	*1.095*	0	7416	61.1
neos-1330635	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
neos-1337307	limit	550624	limit	1.000	519092	**0.943**	0	766	72.6	limit	1.000	572372	1.039	0	530	46.2
	limit	540197	limit	1.000	520962	0.964	0	682	74.3	limit	1.000	281332	**0.521**	0	339	44.5
	limit	623318	limit	1.000	616758	0.989	0	866	69.8	limit	1.000	621340	0.997	0	922	49.2
	limit	604681	limit	1.000	628491	1.039	0	630	68.9	limit	1.000	581707	0.962	0	592	48.3
neos-1346382	limit	12652088	limit	1.000	11436191	**0.904**	0	36595	48.2	limit	1.000	12060292	0.953	0	17286	42.3
	limit	11564496	limit	1.000	9700966	**0.839**	0	75197	46.2	limit	1.000	10088400	**0.872**	0	60486	43.5
	limit	13197521	limit	1.000	11557335	**0.876**	0	28211	45.9	limit	1.000	11090665	**0.840**	0	33805	42.6
	limit	10929778	limit	1.000	11427824	1.046	0	31876	46.1	limit	1.000	9877437	**0.904**	0	77951	44.9
neos-1354092	limit	294	limit	1.000	192	**0.741**	0	4	672.7	limit	1.000	191	**0.739**	0	5	421.0
	limit	567	limit	1.000	1911	*3.015*	0	4	614.5	limit	1.000	1048	*1.721*	0	2	547.2
	limit	182	limit	1.000	101	**0.713**	0	7	598.3	limit	1.000	164	**0.936**	0	6	510.2
	limit	441	limit	1.000	879	*1.810*	0	2	618.0	limit	1.000	672	*1.427*	0	9	527.7
neos-1367061	27.8	1	27.9	1.005	1	1.000	0	0	0.0	28.4	1.022	1	1.000	0	0	0.0
	30.2	1	30.2	0.999	1	1.000	0	0	0.0	30.2	0.998	1	1.000	0	0	0.0
	31.6	1	31.7	1.001	1	1.000	0	0	0.0	31.6	1.000	1	1.000	0	0	0.0
	32.1	1	32.2	1.003	1	1.000	0	0	0.0	32.3	1.005	1	1.000	0	0	0.0
neos-1396125	89.5	12253	168.3	*1.870*	15392	*1.254*	0	40	32.1	74.7	**0.837**	9564	**0.782**	0	14	21.0
	195.8	14783	127.6	**0.653**	8226	**0.559**	0	86	28.3	217.4	*1.110*	11058	**0.750**	0	24	23.5
	94.6	9731	123.5	*1.303*	10313	*1.059*	0	25	25.9	102.3	*1.081*	12153	*1.246*	0	93	26.2
	158.3	18443	158.3	1.000	12053	**0.655**	0	70	32.5	192.6	*1.215*	10429	**0.568**	0	63	27.5
neos-1407044	limit	68	limit	1.000	81	*1.077*	0	0	1213.5	limit	1.000	80	*1.071*	0	0	1303.0
	limit	80	limit	1.000	80	1.000	0	0	1278.0	limit	1.000	77	0.983	0	0	708.0
	limit	65	limit	1.000	89	*1.145*	0	0	272.0	limit	1.000	70	1.030	0	0	241.0
	limit	90	limit	1.000	78	**0.937**	0	0	1083.0	limit	1.000	72	**0.905**	0	0	1080.0
neos-1413153	6.4	3	6.4	1.007	3	1.000	0	0	0.0	6.3	0.999	3	1.000	0	0	0.0
	3.8	2	3.8	0.996	2	1.000	0	0	0.0	3.8	0.998	2	1.000	0	0	0.0
	4.1	2	4.0	0.990	2	1.000	0	0	0.0	4.0	0.992	2	1.000	0	0	0.0
	3.6	2	3.6	1.002	2	1.000	0	0	0.0	3.6	1.002	2	1.000	0	0	0.0
neos-1415183	7.3	2	7.3	0.994	2	1.000	0	0	0.0	7.5	1.025	2	1.000	0	0	0.0
	6.9	2	6.9	1.003	2	1.000	0	0	0.0	6.9	1.001	2	1.000	0	0	0.0
	8.0	2	7.9	0.993	2	1.000	0	0	0.0	7.9	0.991	2	1.000	0	0	0.0
	5.5	1	5.5	0.997	1	1.000	0	0	0.0	5.5	1.002	1	1.000	0	0	0.0
neos-1417043	1732.0	1	1733.6	1.001	1	1.000	0	0	0.0	1731.2	1.000	1	1.000	0	0	0.0
	1531.1	1	1530.4	1.000	1	1.000	0	0	0.0	1531.1	1.000	1	1.000	0	0	0.0
	1617.7	1	1619.8	1.001	1	1.000	0	0	0.0	1624.8	1.004	1	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: CONFLICT DIVING

Instance	nolockdiving		coefdiving							confdiving						
	T	**N**	**T**	**T$_Q$**	**N**	**N$_Q$**	**F**	**C**	**D$_\emptyset$**	**T**	**T$_Q$**	**N**	**N$_Q$**	**F**	**C**	**D$_\emptyset$**
	1503.7	1	1505.2	1.001	1	1.000	0	0	0.0	1506.5	1.002	1	1.000	0	0	0.0
neos-1420205	10.1	14141	4.9	**0.530**	4297	**0.309**	0	38	29.1	6.2	**0.645**	6862	**0.489**	0	44	26.4
	3.5	2689	5.0	*1.341*	4342	*1.593*	0	39	28.2	3.1	**0.922**	2699	1.004	0	23	26.7
	7.3	10217	7.1	0.985	8626	**0.846**	0	59	27.7	6.7	**0.926**	8135	**0.798**	0	98	28.6
	3.4	2902	4.2	*1.176*	3874	*1.324*	0	11	28.2	4.6	*1.260*	5732	*1.943*	0	18	28.2
neos-1420546	limit	2239	limit	1.000	5848	*2.543*	0	0	545.0	limit	1.000	2289	1.021	0	0	0.0
	limit	4374	limit	1.000	5479	*1.247*	0	0	547.5	limit	1.000	4566	1.043	0	0	0.0
	limit	1462	limit	1.000	1935	*1.303*	0	0	554.1	limit	1.000	1462	1.000	0	0	0.0
	limit	4072	limit	1.000	2687	**0.668**	0	0	470.4	limit	1.000	4073	1.000	0	0	0.0
neos-1420790	limit	127573	limit	1.000	148296	*1.162*	0	0	110.8	limit	1.000	134481	*1.054*	0	0	294.3
	limit	154632	limit	1.000	139648	**0.903**	0	128	110.3	limit	1.000	117577	**0.761**	0	0	247.0
	limit	138001	limit	1.000	112886	**0.818**	0	0	107.4	limit	1.000	111161	**0.806**	0	0	286.2
	limit	122735	limit	1.000	98065	**0.799**	0	0	118.0	limit	1.000	106706	**0.870**	0	0	304.8
neos-1423785	limit	26391	limit	1.000	10681	**0.407**	0	36	101.2	limit	1.000	38374	*1.452*	0	19	423.4
	limit	39756	limit	1.000	43289	*1.089*	0	35	186.7	limit	1.000	31905	**0.803**	1	58	490.5
	limit	56141	limit	1.000	51489	**0.917**	0	66	278.2	limit	1.000	48203	**0.859**	1	56	474.8
	limit	27109	limit	1.000	41725	*1.537*	0	41	375.1	limit	1.000	27609	1.018	1	55	457.4
neos-1425699	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
neos-1426662	limit	4566559	limit	1.000	4436654	0.972	0	366	68.3	limit	1.000	5672903	*1.242*	0	920	45.4
	limit	6339847	limit	1.000	5314944	**0.838**	0	3000	67.6	limit	1.000	6127507	0.967	0	2093	45.3
	limit	6062638	limit	1.000	5602191	**0.924**	1	1315	66.9	limit	1.000	5393236	**0.890**	0	4105	43.8
	limit	3031571	limit	1.000	3582059	*1.182*	1	150	81.9	limit	1.000	3619012	*1.194*	0	1159	51.4
neos-1427181	2392.6	1395555	5010.0	*2.094*	1573037	*1.127*	0	419	72.4	942.3	**0.394**	675951	**0.484**	0	926	44.7
	2203.4	2076899	5096.5	*2.312*	4245564	*2.044*	0	404	68.5	1603.8	**0.728**	1346043	**0.648**	0	843	48.5
	limit	5068437	2838.0	**0.394**	1890627	**0.373**	0	521	74.5	4035.7	**0.561**	2300556	**0.454**	0	319	44.5
	limit	4777442	1043.4	**0.145**	874110	**0.183**	0	398	72.8	1075.3	**0.149**	817993	**0.171**	0	397	46.3
neos-1427261	limit	2115433	limit	1.000	1019996	**0.482**	0	345	95.3	limit	1.000	1809640	**0.855**	0	271	63.1
	limit	1135306	limit	1.000	2720384	*2.396*	0	300	93.5	limit	1.000	1086258	0.957	0	387	66.0
	limit	1716909	limit	1.000	1147552	**0.668**	0	317	93.0	limit	1.000	923048	**0.538**	0	315	63.6
	limit	4123449	limit	1.000	980822	**0.238**	0	282	88.4	limit	1.000	2643123	**0.641**	0	604	66.4
neos-1429185	limit	5003699	limit	1.000	5404203	*1.080*	0	503	62.1	limit	1.000	5700379	*1.139*	0	524	53.5
	limit	5148536	limit	1.000	5512169	*1.071*	0	867	60.8	limit	1.000	5223286	1.015	0	432	56.6
	limit	5026739	limit	1.000	5816431	*1.157*	0	249	62.3	limit	1.000	4907189	0.976	0	443	56.6

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	5886519	limit	1.000	4875509	**0.828**	0	469	66.0	limit	1.000	5559729	**0.944**	0	1471	60.8
neos-1429212	limit	4635	limit	1.000	11363	*2.421*	0	277	156.7	limit	1.000	5216	*1.123*	0	0	990.5
	limit	8876	limit	1.000	5609	**0.636**	0	237	122.0	limit	1.000	4439	**0.506**	0	13	852.5
	limit	5837	limit	1.000	5412	**0.928**	0	599	341.0	limit	1.000	5559	0.953	0	3	945.5
	limit	3919	limit	1.000	5018	*1.273*	0	291	312.0	limit	1.000	4876	*1.238*	0	3	929.5
neos-1429461	limit	6714639	limit	1.000	6749722	1.005	0	24315	51.1	limit	1.000	6889826	1.026	0	18217	47.8
	limit	6899835	limit	1.000	7244667	1.050	0	14506	50.9	limit	1.000	6016141	**0.872**	0	25338	49.2
	limit	7824921	limit	1.000	6369347	**0.814**	0	39033	52.1	limit	1.000	7053914	**0.901**	0	33962	47.0
	limit	6403242	limit	1.000	6205480	0.969	0	22537	53.2	limit	1.000	6089830	0.951	0	19390	50.1
neos-1430701	35.4	35157	31.0	**0.879**	31119	**0.885**	0	205	29.5	38.5	*1.087*	40077	*1.140*	0	316	26.1
	19.0	18768	20.1	*1.058*	16303	**0.869**	0	161	30.6	17.6	**0.932**	15586	**0.831**	0	258	25.2
	37.2	38753	26.8	**0.729**	26433	**0.683**	0	205	28.0	42.2	*1.132*	49210	*1.269*	1	472	27.2
	11.2	6707	13.8	*1.211*	11121	*1.648*	0	131	27.4	10.8	0.966	6120	**0.914**	0	128	23.6
neos-1430811	limit	986	limit	1.000	1548	*1.517*	0	187	931.2	limit	1.000	1041	*1.051*	0	0	1099.7
	limit	1003	limit	1.000	2058	*1.956*	0	85	743.4	limit	1.000	831	**0.844**	0	0	1091.7
	limit	1305	limit	1.000	1351	1.033	0	91	909.9	limit	1.000	985	**0.772**	0	0	1140.5
	limit	1262	limit	1.000	1525	*1.193*	0	183	901.7	limit	1.000	1266	1.003	0	0	1176.0
neos-1436709	limit	3493688	limit	1.000	4082734	*1.169*	0	5576	58.5	limit	1.000	3584478	1.026	0	5950	54.8
	limit	3544380	limit	1.000	3732642	*1.053*	0	5069	59.1	limit	1.000	3463675	0.977	0	3924	55.1
	limit	3429387	limit	1.000	3657279	*1.066*	0	8364	60.0	limit	1.000	3460216	1.009	0	4599	55.6
	limit	3617777	limit	1.000	3439058	0.951	0	8075	60.3	limit	1.000	3738664	1.033	0	4285	54.0
neos-1436713	limit	948971	limit	1.000	1050114	*1.107*	0	160	120.4	limit	1.000	1213222	*1.278*	0	239	79.3
	limit	1599280	limit	1.000	1714856	*1.072*	0	271	110.5	limit	1.000	825047	**0.516**	0	127	79.8
	limit	1354564	limit	1.000	2378033	*1.756*	0	178	110.0	limit	1.000	638916	**0.472**	0	254	76.0
	limit	1689187	limit	1.000	1308644	**0.775**	0	184	116.2	limit	1.000	1096796	**0.649**	0	208	77.9
neos-1437164	1.1	1	1.0	0.967	1	1.000	0	0	0.0	0.7	**0.796**	1	1.000	0	0	0.0
	0.7	1	0.7	0.994	1	1.000	0	0	0.0	0.7	0.988	1	1.000	0	0	0.0
	1.1	2	1.1	1.005	2	1.000	0	0	0.0	1.1	0.995	2	1.000	0	0	0.0
	0.7	1	0.7	1.006	1	1.000	0	0	0.0	0.7	1.000	1	1.000	0	0	0.0
neos-1439395	128.6	160501	142.1	*1.104*	193227	*1.204*	0	1052	34.2	75.5	**0.590**	91643	**0.571**	0	483	30.7
	694.8	1021619	640.2	**0.922**	969820	**0.949**	0	3176	37.6	569.5	**0.820**	881350	**0.863**	0	2566	35.3
	127.0	175742	109.9	**0.866**	155192	**0.883**	1	693	33.2	111.2	**0.876**	155004	**0.882**	0	613	32.0
	287.9	408814	245.1	**0.852**	366979	**0.898**	0	964	36.6	561.7	*1.948*	878489	*2.149*	0	2360	35.8
neos-1440225	67.7	2790	35.5	**0.532**	1345	**0.500**	0	10	26.0	39.5	**0.590**	1574	**0.579**	0	10	74.0
	62.9	2558	79.4	*1.258*	3402	*1.318*	0	7	119.0	44.1	**0.706**	1690	**0.673**	0	8	158.0
	5.3	3	5.3	1.003	3	1.000	0	0	0.0	5.3	1.003	3	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	17.3	259	17.2	0.995	259	1.000	0	0	0.0	17.3	0.998	259	1.000	0	0	0.0
neos-1440447	7.2	4124	8.1	*1.108*	5142	*1.241*	0	63	26.4	7.3	1.020	3658	**0.890**	0	34	21.3
	4.7	2415	3.7	**0.821**	2105	**0.877**	0	23	25.9	3.5	**0.782**	2043	**0.852**	0	33	21.6
	10.5	7098	10.5	0.997	8147	*1.146*	0	81	26.9	12.4	*1.159*	10245	*1.437*	0	127	23.3
	3.1	1074	3.1	0.995	1249	*1.149*	0	19	27.6	3.2	1.007	1286	*1.181*	0	4	24.2
neos-1440457	limit	2742825	limit	1.000	2943940	*1.073*	0	5460	72.3	limit	1.000	2911141	*1.061*	0	7097	68.5
	limit	2967055	limit	1.000	2384549	**0.804**	0	5377	74.3	limit	1.000	2794608	**0.942**	0	3653	69.9
	limit	3243350	limit	1.000	3023907	**0.932**	0	6574	70.6	limit	1.000	2905620	**0.896**	0	8602	68.0
	limit	2484400	limit	1.000	3283815	*1.322*	0	6399	74.2	limit	1.000	2940017	*1.183*	0	4679	65.7
neos-1440460	4609.2	5856899	3378.4	**0.733**	4260679	**0.727**	0	6886	47.8	3213.2	**0.697**	4362569	**0.745**	2	9935	44.4
	limit	9224720	limit	1.000	8139980	**0.882**	0	15506	49.1	limit	1.000	6606527	**0.716**	0	24145	47.5
	limit	7027860	limit	1.000	7243157	1.031	0	11676	49.7	limit	1.000	7834504	*1.115*	0	15653	46.1
	limit	6734276	limit	1.000	6945870	1.031	1	23662	49.7	limit	1.000	7432642	*1.104*	0	14317	45.6
neos-1441553	2.8	1	2.7	0.987	1	1.000	0	0	0.0	3.1	*1.101*	1	1.000	0	0	0.0
	3.3	2	3.2	0.979	2	1.000	0	0	0.0	3.2	0.977	2	1.000	0	0	0.0
	4.5	2	4.5	1.000	2	1.000	0	0	0.0	4.5	0.996	2	1.000	0	0	0.0
	2.8	5	2.7	0.997	5	1.000	0	0	0.0	2.8	1.013	5	1.000	0	0	0.0
neos-1442119	limit	2744293	limit	1.000	2895614	*1.055*	0	9739	63.0	limit	1.000	2783214	1.014	0	3072	57.2
	limit	2701271	limit	1.000	2570477	0.952	0	6508	63.5	limit	1.000	2431827	**0.900**	0	3809	58.7
	limit	2816183	limit	1.000	2480552	**0.881**	0	7197	64.4	limit	1.000	2675359	**0.950**	0	4846	63.0
	limit	2765828	limit	1.000	2577423	**0.932**	0	4785	65.7	limit	1.000	2583663	**0.934**	0	2957	58.3
neos-1442657	limit	3999231	limit	1.000	3425428	**0.857**	0	12637	57.0	limit	1.000	3677872	**0.920**	1	11021	52.3
	limit	3302164	limit	1.000	3034775	**0.919**	0	8948	57.3	limit	1.000	3483745	*1.055*	0	15353	53.2
	limit	3647668	limit	1.000	3967245	*1.088*	0	12284	56.6	limit	1.000	3631569	0.996	1	16053	52.4
	limit	3627019	limit	1.000	3637813	1.003	0	18633	56.5	limit	1.000	3308716	**0.912**	0	14235	53.5
neos-1445532	limit	1351	limit	1.000	1671	*1.221*	0	136	63.9	limit	1.000	939	**0.716**	1	271	48.6
	limit	508	limit	1.000	444	**0.895**	0	240	57.1	limit	1.000	624	*1.191*	1	546	55.8
	limit	657	limit	1.000	745	*1.116*	1	84	80.1	limit	1.000	647	0.987	1	113	47.8
	limit	868	limit	1.000	1309	*1.456*	1	63	58.7	limit	1.000	1013	*1.150*	1	932	65.1
neos-1445738	limit	20423	limit	1.000	22762	*1.114*	0	40	98.0	limit	1.000	15661	**0.768**	1	44	52.3
	limit	18575	limit	1.000	18994	1.022	2	121	80.2	limit	1.000	17291	**0.931**	5	390	56.9
	limit	14035	limit	1.000	13782	0.982	1	84	100.7	limit	1.000	13213	**0.942**	1	101	61.9
	limit	26942	limit	1.000	29902	*1.109*	0	0	108.5	limit	1.000	26232	0.974	0	21	51.9
neos-1445743	52.8	3	54.2	1.026	3	1.000	0	0	0.0	52.7	0.999	3	1.000	0	0	0.0
	62.1	3	62.2	1.002	3	1.000	0	0	0.0	61.8	0.995	3	1.000	0	0	0.0
	52.2	3	52.7	1.010	3	1.000	0	0	0.0	52.3	1.003	3	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	63.4	3	63.5	1.002	3	1.000	0	0	0.0	64.5	1.017	3	1.000	0	0	0.0
neos-1445755	60.7	3	61.0	1.004	3	1.000	0	0	0.0	61.1	1.007	3	1.000	0	0	0.0
	56.6	3	56.7	1.001	3	1.000	0	0	0.0	56.5	0.998	3	1.000	0	0	0.0
	58.2	3	57.9	0.995	3	1.000	0	0	0.0	57.5	0.987	3	1.000	0	0	0.0
	67.0	4	67.7	1.010	4	1.000	0	0	0.0	67.1	1.001	4	1.000	0	0	0.0
neos-1445765	67.4	86	67.5	1.002	86	1.000	0	0	0.0	66.9	0.993	86	1.000	0	0	0.0
	83.5	3	83.4	0.999	3	1.000	0	0	0.0	82.2	0.985	3	1.000	0	0	0.0
	97.6	7	99.6	1.020	7	1.000	0	0	0.0	97.3	0.997	7	1.000	0	0	0.0
	67.6	91	65.8	0.974	91	1.000	0	0	0.0	67.3	0.996	91	1.000	0	0	0.0
neos-1451294	1581.4	3462	593.7	**0.376**	886	**0.277**	0	169	89.1	450.5	**0.285**	393	**0.138**	0	21	124.5
	2230.7	6352	3493.6	*1.566*	5972	**0.941**	0	147	60.5	2596.9	*1.164*	4692	**0.743**	0	166	87.3
	1322.4	3693	1096.2	**0.829**	2965	**0.808**	0	443	45.6	1517.6	*1.148*	3916	*1.059*	0	123	118.5
	3620.2	20251	1661.2	**0.459**	5308	**0.266**	0	286	73.5	2005.2	**0.554**	11750	**0.582**	0	292	78.7
neos-1456979	limit	22764	limit	1.000	95857	*4.197*	0	618	60.4	limit	1.000	38892	*1.705*	0	378	53.1
	limit	22013	limit	1.000	32133	*1.458*	0	344	71.6	limit	1.000	120914	*5.473*	0	1221	45.5
	limit	27195	3303.3	**0.459**	120347	*4.413*	0	786	52.1	limit	1.000	31847	*1.170*	0	259	42.9
	6417.5	116850	limit	*1.122*	35691	**0.306**	0	193	85.0	limit	*1.122*	31539	**0.271**	0	336	41.4
neos-1460246	limit	3801136	limit	1.000	4514836	*1.188*	0	1473	49.4	limit	1.000	5135211	*1.351*	0	2539	50.3
	limit	5280019	limit	1.000	3517950	**0.666**	0	679	52.2	limit	1.000	4377264	**0.829**	0	433	53.5
	limit	3388568	limit	1.000	3919735	*1.157*	0	780	52.4	limit	1.000	4038543	*1.192*	0	743	49.5
	limit	3701943	limit	1.000	4559471	*1.232*	0	714	50.1	limit	1.000	3680684	0.994	0	1435	55.6
neos-1460265	10.1	341	7.3	**0.750**	60	**0.363**	0	1	102.0	7.1	**0.729**	121	**0.501**	0	1	58.0
	5.9	83	6.5	*1.082*	94	*1.060*	0	7	40.0	7.7	*1.251*	96	*1.071*	0	0	0.0
	3.0	1	3.2	1.030	1	1.000	0	0	0.0	3.1	1.020	1	1.000	0	0	0.0
	7.3	120	5.1	**0.736**	42	**0.645**	0	0	0.0	5.0	**0.722**	42	**0.645**	0	0	0.0
neos-1460543	limit	20801	limit	1.000	17296	**0.832**	0	0	413.7	limit	1.000	16343	**0.787**	0	0	448.0
	limit	7875	limit	1.000	19330	*2.436*	0	0	419.9	limit	1.000	33230	*4.179*	0	0	461.0
	limit	16144	limit	1.000	31158	*1.924*	0	0	419.5	limit	1.000	12253	**0.760**	0	0	441.7
	limit	22114	limit	1.000	14494	**0.657**	0	0	430.4	limit	1.000	15622	**0.708**	0	4	365.0
neos-1460641	limit	585894	limit	1.000	699788	*1.194*	0	596	158.8	limit	1.000	585364	0.999	0	449	215.1
	limit	524768	limit	1.000	627871	*1.196*	0	452	149.5	limit	1.000	659017	*1.256*	0	544	209.9
	limit	615102	limit	1.000	616282	1.002	0	450	160.1	limit	1.000	518992	**0.844**	0	291	247.0
	limit	617955	limit	1.000	687210	*1.112*	0	386	173.6	limit	1.000	425191	**0.688**	0	313	229.4
neos-1461051	39.8	3694	40.7	1.021	3960	*1.070*	0	5	18.0	37.2	**0.935**	3542	0.960	0	3	18.0
	36.8	2539	36.8	1.001	2539	1.000	0	0	0.0	36.6	0.995	2539	1.000	0	0	0.0
	48.2	4164	48.0	0.997	4164	1.000	0	0	0.0	48.1	0.999	4164	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	40.5	3816	40.6	1.003	3816	1.000	0	0	0.0	40.6	1.002	3816	1.000	0	0	0.0
neos-1464762	limit	790473	limit	1.000	918081	*1.161*	0	406	302.5	limit	1.000	725833	**0.918**	0	1226	167.9
	limit	704985	limit	1.000	764406	*1.084*	0	289	379.0	limit	1.000	968249	*1.373*	0	903	171.8
	limit	870777	limit	1.000	403902	**0.464**	0	1231	259.6	limit	1.000	484279	**0.556**	0	3179	164.2
	limit	499124	limit	1.000	686472	*1.375*	0	372	287.3	limit	1.000	476782	0.955	0	3315	168.6
neos-1467067	limit	9290197	limit	1.000	9384002	1.010	0	10085	46.8	limit	1.000	9719434	1.046	0	10961	41.3
	limit	10490236	limit	1.000	10612547	1.012	0	15841	46.3	limit	1.000	10638389	1.014	0	20529	41.5
	limit	10106933	limit	1.000	9015310	**0.892**	0	13986	45.5	limit	1.000	10415056	1.030	0	11168	40.0
	limit	8401202	limit	1.000	10787940	*1.284*	0	23324	45.5	limit	1.000	9148285	*1.089*	0	12384	41.1
neos-1467371	limit	605077	limit	1.000	951942	*1.573*	0	543	261.1	limit	1.000	829215	*1.370*	0	589	160.5
	limit	466861	limit	1.000	906973	*1.943*	0	433	257.9	limit	1.000	629307	*1.348*	0	733	160.2
	limit	662648	limit	1.000	690069	1.041	0	415	267.5	limit	1.000	254522	**0.384**	0	950	153.3
	limit	414250	limit	1.000	591462	*1.428*	0	251	289.5	limit	1.000	732426	*1.768*	0	2425	175.9
neos-1467467	limit	187492	limit	1.000	185504	0.989	0	100	375.5	limit	1.000	148781	**0.794**	0	381	153.8
	limit	141831	limit	1.000	180971	*1.276*	0	96	407.5	limit	1.000	197746	*1.394*	0	240	155.3
	limit	252598	limit	1.000	152842	**0.605**	0	157	375.1	limit	1.000	159141	**0.630**	0	249	149.8
	limit	189118	limit	1.000	178289	**0.943**	0	58	458.2	limit	1.000	152865	**0.808**	0	95	172.6
neos-1480121	3.1	6441	4.0	*1.226*	8588	*1.328*	0	0	41.9	3.3	1.049	7190	*1.115*	0	0	41.6
	0.6	41	0.6	1.038	106	*1.461*	0	0	0.0	0.6	1.019	107	*1.468*	0	0	0.0
	16.6	207	16.4	0.990	207	1.000	0	0	0.0	16.5	0.994	207	1.000	0	0	0.0
	2.2	3109	1.1	**0.659**	858	**0.299**	0	5	18.8	1.1	**0.663**	1321	**0.443**	0	6	23.2
neos-1489999	3.9	30	3.9	0.998	30	1.000	0	0	0.0	4.2	*1.076*	30	1.000	0	0	0.0
	3.4	23	3.4	1.000	23	1.000	0	0	0.0	3.5	1.009	23	1.000	0	0	0.0
	3.4	31	3.4	1.014	31	1.000	0	0	0.0	3.4	1.007	31	1.000	0	0	0.0
	4.0	26	3.9	0.988	26	1.000	0	0	0.0	3.8	0.972	26	1.000	0	0	0.0
neos-1516309	0.9	1	0.6	**0.824**	1	1.000	0	0	0.0	0.5	**0.814**	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
neos-1582420	39.6	494	42.8	*1.079*	712	*1.367*	0	11	52.0	29.4	**0.751**	198	**0.502**	0	6	165.0
	34.5	460	34.2	0.990	460	1.000	0	0	0.0	34.3	0.994	460	1.000	0	0	0.0
	41.6	234	35.4	**0.853**	237	1.009	0	0	0.0	34.4	**0.831**	225	0.973	0	0	0.0
	46.6	14	46.5	0.999	14	1.000	0	0	0.0	46.2	0.991	14	1.000	0	0	0.0
neos-1593097	limit	63397	limit	1.000	48493	**0.765**	0	554	296.1	limit	1.000	53881	**0.850**	0	1174	104.0
	limit	37108	limit	1.000	36296	0.978	0	575	229.8	limit	1.000	43824	*1.180*	0	1307	88.9
	limit	61059	limit	1.000	46014	**0.754**	0	872	228.6	limit	1.000	57185	**0.937**	0	2052	113.3

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	34145	limit	1.000	44450	*1.301*	0	1228	204.7	limit	1.000	41328	*1.210*	0	331	91.5
neos-1595230	299.6	45171	289.4	0.966	38974	**0.863**	0	125	89.3	273.4	**0.913**	36783	**0.815**	0	285	30.9
	1022.8	202417	412.8	**0.404**	63703	**0.315**	0	121	88.0	1073.6	1.050	217973	*1.077*	0	158	29.9
	255.8	39419	248.3	0.971	35227	**0.894**	0	50	88.3	292.9	*1.144*	47002	*1.192*	0	197	38.6
	681.5	97082	696.6	1.022	99743	1.027	0	50	99.0	666.0	0.977	105447	*1.086*	0	111	33.6
neos-1597104	237.9	5	240.3	1.010	5	1.000	0	0	0.0	237.8	0.999	5	1.000	0	0	0.0
	234.3	5	232.6	0.993	5	1.000	0	0	0.0	232.5	0.992	5	1.000	0	0	0.0
	245.1	5	245.8	1.003	5	1.000	0	0	0.0	242.5	0.990	5	1.000	0	0	0.0
	335.6	12	335.7	1.000	12	1.000	0	0	0.0	319.9	0.954	6	**0.946**	0	0	0.0
neos-1599274	1.2	1	1.3	1.018	1	1.000	0	0	0.0	1.3	1.013	1	1.000	0	0	0.0
	1.1	1	1.1	0.991	1	1.000	0	0	0.0	1.1	1.005	1	1.000	0	0	0.0
	0.9	1	0.9	1.038	1	1.000	0	0	0.0	0.9	1.016	1	1.000	0	0	0.0
	1.0	1	1.1	1.020	1	1.000	0	0	0.0	1.0	1.000	1	1.000	0	0	0.0
neos-1601936	6810.1	7493	3807.7	**0.559**	5687	**0.762**	0	150	293.2	4029.8	**0.592**	5844	**0.783**	0	4	375.4
	limit	6513	limit	1.000	7280	*1.116*	0	373	317.3	limit	1.000	12104	*1.845*	0	57	320.1
	3382.5	5888	5916.6	*1.749*	12107	*2.039*	0	1558	181.9	3205.3	**0.948**	5537	**0.941**	0	213	284.8
	limit	22784	2278.2	**0.317**	1106	**0.053**	0	240	255.4	2586.9	**0.359**	3658	**0.164**	0	232	249.0
neos-1603512	3.1	13	2.9	0.954	13	1.000	0	0	0.0	3.0	0.973	13	1.000	0	0	0.0
	2.2	14	2.2	1.003	14	1.000	0	0	0.0	2.3	1.015	14	1.000	0	0	0.0
	3.5	23	3.5	1.011	23	1.000	0	21	21.0	2.8	**0.859**	8	**0.878**	1	0	58.0
	2.5	11	2.5	0.989	11	1.000	0	0	0.0	2.6	1.006	11	1.000	0	0	0.0
neos-1603518	8.3	26	7.8	0.950	27	1.008	0	33	26.0	8.8	*1.060*	32	1.048	0	2	31.0
	8.3	31	8.3	0.999	31	1.000	0	0	0.0	8.4	1.001	31	1.000	0	0	0.0
	9.5	44	9.4	0.997	44	1.000	0	0	0.0	9.5	1.005	44	1.000	0	0	0.0
	8.7	31	9.3	*1.063*	35	1.031	0	39	23.0	10.9	*1.231*	48	*1.130*	0	8	93.0
neos-1605061	limit	875	limit	1.000	862	0.987	0	13	478.4	limit	1.000	592	**0.710**	0	4	237.0
	limit	872	limit	1.000	849	0.976	0	16	495.5	limit	1.000	987	*1.118*	0	22	162.5
	limit	805	limit	1.000	963	*1.175*	0	27	455.5	limit	1.000	705	**0.890**	0	5	299.8
	limit	796	limit	1.000	652	**0.839**	0	4	376.4	limit	1.000	790	0.993	0	28	274.0
neos-1605075	limit	3792	4995.2	**0.694**	1724	**0.469**	0	42	379.8	7004.0	0.973	3460	**0.915**	0	569	216.0
	limit	8303	6666.6	**0.926**	7388	**0.891**	0	124	296.6	limit	1.000	10799	*1.297*	0	326	231.6
	4402.8	1754	limit	*1.635*	5106	*2.808*	0	253	342.2	limit	*1.635*	5838	*3.203*	0	184	222.4
	limit	4353	limit	1.000	2908	**0.675**	0	110	386.8	limit	1.000	2071	**0.488**	0	88	412.8
neos-1616732	5630.2	1355685	4503.3	**0.800**	1006387	**0.742**	0	0	35.8	5626.3	0.999	1355685	1.000	0	0	0.0
	5096.6	1368476	4623.3	**0.907**	1126050	**0.823**	0	0	35.8	5082.6	0.997	1368476	1.000	0	0	0.0
	4106.7	1166055	4010.5	0.977	1193963	1.024	0	0	38.4	4130.2	1.006	1166055	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	3857.7	1010100	3837.7	0.995	968298	0.959	0	0	37.3	3866.4	1.002	1010100	1.000	0	0	0.0
neos-1620770	limit	1534346	limit	1.000	1802725	*1.175*	0	46836	33.3	limit	1.000	1370375	**0.893**	0	35417	33.8
	limit	1861794	limit	1.000	1786068	0.959	0	51068	34.0	limit	1.000	1574495	**0.846**	0	99493	29.9
	limit	1500316	limit	1.000	1252537	**0.835**	0	227888	32.5	limit	1.000	1729156	*1.153*	0	83548	31.8
	limit	1675101	limit	1.000	1433144	**0.856**	0	65667	33.4	limit	1.000	1639501	0.979	0	30571	32.6
neos-1620807	9.0	2668	9.2	1.020	2706	1.014	0	100	19.5	9.0	1.007	2696	1.010	0	83	17.3
	6.4	665	5.6	**0.896**	665	1.000	0	0	0.0	5.6	**0.896**	665	1.000	0	0	0.0
	8.3	1432	8.4	1.007	1388	0.971	0	143	20.6	8.4	1.007	1398	0.978	0	141	18.7
	8.5	355	8.5	1.001	355	1.000	0	0	0.0	8.4	0.991	355	1.000	0	0	0.0
neos-1622252	2841.1	774122	5207.4	*1.833*	1285515	*1.661*	0	115234	33.4	limit	*2.534*	1554272	*2.008*	0	291014	33.2
	2561.8	699877	2651.7	1.035	716449	1.024	0	97447	31.7	3614.5	*1.411*	964131	*1.378*	0	126843	30.7
	limit	1415241	limit	1.000	1298991	**0.918**	0	496675	38.8	limit	1.000	1120971	**0.792**	0	405818	35.9
	limit	1529176	3292.9	**0.457**	976272	**0.638**	0	153624	35.5	2323.9	**0.323**	719028	**0.470**	0	103400	29.0
neos-430149	42.0	32482	41.4	0.986	31870	0.981	0	86	36.7	33.5	**0.804**	23998	**0.740**	0	93	30.9
	49.3	44565	45.3	**0.920**	37959	**0.852**	0	90	32.6	36.5	**0.745**	30015	**0.674**	0	78	28.0
	34.0	26559	35.7	1.049	28281	*1.065*	0	66	36.5	34.5	1.013	27640	1.041	0	118	31.1
	40.5	31132	34.2	**0.847**	25965	**0.835**	0	111	34.1	28.8	**0.718**	21817	**0.702**	0	82	29.5
neos-476283	170.2	476	174.0	1.022	405	**0.877**	0	5	24.5	177.3	1.041	386	**0.844**	0	7	26.0
	174.9	338	173.6	0.992	444	*1.242*	0	0	20.0	181.4	1.037	444	*1.242*	0	0	20.0
	247.1	684	224.6	**0.909**	505	**0.772**	0	3	30.0	248.6	1.006	623	**0.922**	0	12	30.5
	173.9	488	149.2	**0.858**	321	**0.716**	0	7	19.5	179.6	1.033	454	**0.942**	0	9	27.3
neos-480878	70.4	12806	85.0	*1.205*	19056	*1.484*	0	100	33.1	46.6	**0.667**	8490	**0.666**	0	75	31.7
	68.6	15473	61.2	**0.895**	9831	**0.638**	1	53	33.5	77.0	*1.121*	14191	**0.918**	1	106	31.2
	48.2	9983	67.1	*1.385*	12219	*1.222*	0	85	32.8	55.1	*1.140*	10050	1.007	0	71	31.6
	54.5	10095	62.3	*1.141*	12264	*1.213*	1	65	35.6	63.9	*1.169*	12038	*1.191*	1	94	30.4
neos-494568	19.9	6	20.0	1.003	6	1.000	0	0	0.0	19.6	0.986	6	1.000	0	0	0.0
	29.1	6	25.5	**0.880**	6	1.000	0	0	0.0	21.4	**0.744**	6	1.000	0	0	0.0
	29.1	6	25.6	**0.882**	6	1.000	0	0	0.0	27.2	**0.936**	6	1.000	0	0	0.0
	20.0	6	20.2	1.010	6	1.000	0	0	0.0	19.1	0.954	6	1.000	0	0	0.0
neos-495307	limit	116210	limit	1.000	136803	*1.177*	83	3	563.2	limit	1.000	153035	*1.317*	5	32	257.3
	limit	151387	limit	1.000	116123	**0.767**	45	4	351.9	limit	1.000	177932	*1.175*	44	137	141.8
	limit	168639	limit	1.000	198298	*1.176*	45	15	332.0	limit	1.000	155163	**0.920**	45	119	139.8
	limit	137174	limit	1.000	156616	*1.142*	10	4	702.8	limit	1.000	175271	*1.278*	5	25	204.8
neos-498623	34.4	6	32.5	**0.945**	6	1.000	0	0	0.0	26.1	**0.766**	6	1.000	0	0	0.0
	30.1	6	32.5	*1.077*	6	1.000	0	0	0.0	44.5	*1.464*	8	1.019	0	0	46.0
	39.8	8	59.5	*1.485*	21	*1.120*	0	0	0.0	58.8	*1.467*	21	*1.120*	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

Instance	nolockdiving		coefdiving							confdiving						
	T	**N**	**T**	**T_Q**	**N**	**N_Q**	**F**	**C**	**$D_\emptyset$**	**T**	**T_Q**	**N**	**N_Q**	**F**	**C**	**$D_\emptyset$**
	52.9	17	43.5	**0.826**	14	0.974	0	0	0.0	32.9	**0.630**	6	**0.906**	0	0	0.0
neos-501453	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
neos-501474	0.5	2	0.5	1.000	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0
	0.5	2	0.5	1.000	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0
	0.5	2	0.5	1.000	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0
	0.8	4	0.8	1.023	4	1.000	0	0	0.0	0.8	1.006	4	1.000	0	0	0.0
neos-503737	329.2	6452	749.4	*2.273*	28994	*4.440*	0	194	101.9	310.3	**0.943**	4762	**0.742**	0	148	171.6
	432.2	12109	802.1	*1.854*	39762	*3.265*	0	923	86.7	219.5	**0.509**	4241	**0.356**	0	542	75.4
	42.2	204	179.8	*4.182*	2168	*7.461*	0	367	93.7	153.8	*3.583*	1409	*4.964*	0	0	242.2
	139.8	2236	171.2	*1.223*	2987	*1.321*	0	205	105.8	93.5	**0.671**	982	**0.463**	0	44	147.8
neos-504674	58.8	6658	71.0	*1.203*	7974	*1.195*	1	29	25.8	62.3	*1.057*	6948	1.043	0	28	25.0
	43.9	4584	61.0	*1.381*	9049	*1.953*	1	30	24.9	50.8	*1.154*	4696	1.024	0	7	24.9
	45.8	5412	50.8	*1.106*	7268	*1.337*	0	38	24.2	40.7	**0.891**	5876	*1.084*	0	12	26.8
	45.6	4839	49.7	*1.088*	5572	*1.148*	0	10	19.6	48.1	*1.055*	5271	*1.087*	0	19	24.4
neos-504815	21.5	2382	25.7	*1.187*	2922	*1.218*	1	10	21.0	26.0	*1.203*	3293	*1.367*	0	17	23.2
	21.1	2737	20.5	0.969	2964	*1.080*	0	10	25.0	22.8	*1.075*	3168	*1.152*	1	11	24.2
	21.7	2555	22.6	1.040	3753	*1.451*	2	18	24.1	20.1	**0.929**	2533	0.992	0	10	17.5
	22.6	2749	23.3	1.030	3466	*1.252*	0	19	21.7	21.2	**0.941**	2799	1.018	0	14	16.0
neos-506422	48.2	2953	56.6	*1.171*	4863	*1.626*	0	10	33.4	62.2	*1.286*	5415	*1.806*	1	88	25.1
	114.0	12171	82.5	**0.727**	5962	**0.494**	0	24	29.9	70.0	**0.617**	5012	**0.417**	0	32	23.7
	78.2	5728	80.3	1.026	6295	*1.097*	0	19	32.8	71.2	**0.911**	5440	0.951	0	31	27.2
	76.5	6311	63.9	**0.837**	4681	**0.746**	0	15	29.8	27.9	**0.372**	1231	**0.208**	0	8	24.8
neos-506428	4208.3	492	3851.7	**0.915**	291	**0.660**	0	122	45.3	4928.6	*1.171*	250	**0.591**	0	70	29.0
	4046.8	280	5524.3	*1.365*	230	**0.868**	0	138	39.0	6529.4	*1.613*	250	**0.921**	0	124	25.3
	3102.7	261	5933.1	*1.912*	669	*2.130*	0	132	29.2	4698.6	*1.514*	640	*2.050*	0	93	44.7
	limit	823	4832.6	**0.671**	494	**0.644**	0	2	30.0	limit	1.000	668	**0.832**	0	2	5.0
neos-512201	36.3	3078	35.6	0.983	3009	0.978	0	14	29.6	43.6	*1.197*	3912	*1.262*	0	13	25.8
	28.4	2478	30.4	*1.068*	2635	*1.061*	1	5	28.8	28.1	0.993	2155	**0.875**	0	8	25.8
	25.6	1679	29.9	*1.163*	3373	*1.952*	0	7	25.7	32.5	*1.257*	4201	*2.418*	0	4	29.3
	30.6	2408	29.6	0.969	2500	1.037	0	7	22.3	29.0	**0.949**	2137	**0.892**	0	5	30.7
neos-522351	2.2	1	2.1	0.969	1	1.000	0	0	0.0	2.1	0.963	1	1.000	0	0	0.0
	2.1	1	2.1	1.000	1	1.000	0	0	0.0	2.1	0.997	1	1.000	0	0	0.0
	1.7	2	1.7	1.007	2	1.000	0	0	0.0	1.7	1.011	2	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

Instance	nolockdiving		coefdiving							confdiving						
	T	**N**	**T**	**T$_Q$**	**N**	**N$_Q$**	**F**	**C**	**D$_\emptyset$**	**T**	**T$_Q$**	**N**	**N$_Q$**	**F**	**C**	**D$_\emptyset$**
	1.2	1	1.2	0.991	1	1.000	0	0	0.0	1.2	0.987	1	1.000	0	0	0.0
neos-525149	2.6	1	2.5	0.994	1	1.000	0	0	0.0	2.5	0.994	1	1.000	0	0	0.0
	3.0	1	3.0	0.998	1	1.000	0	0	0.0	3.0	0.988	1	1.000	0	0	0.0
	3.4	2	3.4	0.989	2	1.000	0	0	0.0	3.4	0.993	2	1.000	0	0	0.0
	2.0	1	2.0	1.013	1	1.000	0	0	0.0	1.9	0.987	1	1.000	0	0	0.0
neos-530627	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
neos-538867	80.0	23039	96.3	*1.201*	23809	1.033	0	280	38.9	107.4	*1.338*	29331	*1.272*	0	405	36.4
	133.2	35879	112.8	**0.848**	32887	**0.917**	0	124	46.3	145.2	*1.089*	36335	1.013	0	122	44.2
	55.2	20539	75.6	*1.363*	27978	*1.360*	0	292	34.7	80.7	*1.453*	28003	*1.362*	0	263	38.6
	113.9	28014	141.0	*1.236*	33245	*1.186*	0	157	41.2	144.3	*1.265*	34801	*1.241*	0	127	34.4
neos-538916	41.2	5447	41.2	0.999	5488	1.007	0	60	29.6	40.7	0.989	5554	1.019	1	74	37.9
	33.5	3623	33.3	0.993	3728	1.028	0	64	26.1	33.2	0.992	3918	*1.079*	0	97	28.1
	49.3	8663	36.6	**0.747**	6245	**0.724**	0	67	38.8	45.1	**0.916**	7424	**0.859**	0	163	36.2
	69.8	11679	58.0	**0.833**	8110	**0.697**	0	151	31.5	53.7	**0.772**	7954	**0.684**	0	132	32.8
neos-544324	51.4	97	63.6	*1.232*	206	*1.553*	0	0	327.0	64.7	*1.253*	205	*1.548*	0	83	27.0
	54.9	119	54.3	0.989	119	1.000	0	0	0.0	54.8	0.998	119	1.000	0	0	0.0
	46.8	21	52.7	*1.123*	54	*1.273*	0	0	0.0	47.3	1.009	21	1.000	0	0	0.0
	51.0	46	51.2	1.005	46	1.000	0	0	0.0	51.6	1.011	46	1.000	0	0	0.0
neos-547911	25.2	158	25.1	0.998	158	1.000	0	0	0.0	24.8	0.986	158	1.000	0	0	0.0
	82.0	1207	22.2	**0.280**	133	**0.178**	0	7	136.0	21.2	**0.267**	129	**0.175**	0	13	25.0
	24.4	122	24.6	1.006	122	1.000	0	0	0.0	24.8	1.012	122	1.000	0	0	0.0
	9.5	3	9.3	0.988	3	1.000	0	0	0.0	9.1	0.965	3	1.000	0	0	0.0
neos-548047	limit	45273	limit	1.000	33893	**0.749**	0	73	366.4	limit	1.000	43426	0.959	0	117	60.7
	limit	27321	limit	1.000	31074	*1.137*	0	25	359.2	limit	1.000	30006	*1.098*	0	251	71.8
	limit	35950	limit	1.000	40213	*1.118*	0	120	337.7	limit	1.000	32726	**0.911**	0	229	46.2
	limit	26322	limit	1.000	47646	*1.807*	0	80	462.3	limit	1.000	44383	*1.684*	0	335	53.7
neos-548251	limit	2966027	limit	1.000	3219640	*1.086*	0	337	85.7	limit	1.000	3422153	*1.154*	0	356	76.9
	limit	3522835	limit	1.000	3288402	**0.933**	0	252	91.5	limit	1.000	3254071	**0.924**	0	561	76.7
	limit	3098822	limit	1.000	2885353	**0.931**	0	493	104.9	limit	1.000	2756627	**0.890**	0	372	69.6
	limit	2874265	limit	1.000	2977842	1.036	0	347	95.6	limit	1.000	2911441	1.013	0	254	79.8
neos-551991	151.6	523	176.0	*1.160*	615	*1.148*	0	40	103.4	178.7	*1.178*	556	*1.053*	0	48	23.2
	150.3	522	130.8	**0.871**	665	*1.230*	0	30	100.7	217.2	*1.442*	813	*1.468*	0	158	29.5
	159.5	589	182.6	*1.144*	575	0.980	0	27	98.4	190.6	*1.194*	675	*1.125*	0	63	38.3

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	227.2	902	344.6	*1.515*	1527	*1.624*	0	35	105.8	290.4	*1.277*	1541	*1.638*	0	65	38.4
neos-555001	1.9	1	1.6	**0.884**	1	1.000	0	0	0.0	1.8	0.952	1	1.000	0	0	0.0
	1.0	1	0.9	0.990	1	1.000	0	0	0.0	0.9	0.980	1	1.000	0	0	0.0
	1.1	1	1.1	1.015	1	1.000	0	0	0.0	1.1	1.005	1	1.000	0	0	0.0
	1.4	1	1.4	1.013	1	1.000	0	0	0.0	1.3	0.996	1	1.000	0	0	0.0
neos-555298	97.2	1845	77.5	**0.799**	1100	**0.617**	0	0	267.0	105.1	*1.080*	1721	**0.936**	1	8	214.0
	65.6	471	75.2	*1.144*	1014	*1.951*	0	1	202.0	70.4	*1.073*	729	*1.452*	0	0	201.0
	64.1	602	62.1	0.970	582	0.972	0	18	271.0	50.6	**0.793**	502	**0.858**	0	0	208.0
	47.0	233	74.2	*1.568*	1091	*3.577*	0	5	286.0	56.0	*1.189*	382	*1.447*	0	1	177.0
neos-555343	limit	259436	332.3	**0.046**	13175	**0.051**	0	89	297.5	4252.6	**0.591**	488299	*1.882*	0	9539	225.2
	2863.8	265195	limit	*2.514*	880538	*3.319*	0	3822	221.9	1333.5	**0.466**	122100	**0.461**	0	155	240.3
	2132.4	186702	1551.3	**0.728**	185371	0.993	0	725	244.8	1486.3	**0.697**	116570	**0.625**	0	180	253.5
	limit	312205	1639.2	**0.228**	158908	**0.509**	0	676	267.1	1476.7	**0.205**	179845	**0.576**	1	767	272.5
neos-555424	limit	840135	2552.0	**0.355**	433289	**0.516**	0	1718	262.1	273.9	**0.038**	20865	**0.025**	0	972	246.2
	656.0	86674	508.1	**0.775**	52136	**0.602**	0	233	334.0	2097.6	*3.194*	308098	*3.552*	0	4251	270.4
	549.7	53244	584.6	*1.063*	60699	*1.140*	0	966	271.5	609.9	*1.109*	61003	*1.145*	0	886	254.0
	99.6	5538	1029.5	*10.243*	155876	*27.665*	0	1910	230.6	156.0	*1.560*	7845	*1.409*	0	359	237.3
neos-555694	11.3	21	11.3	1.000	21	1.000	0	0	0.0	11.3	1.002	21	1.000	0	0	0.0
	4.3	6	4.2	0.992	6	1.000	0	0	0.0	4.2	0.998	6	1.000	0	0	0.0
	4.6	6	4.6	1.009	6	1.000	0	0	0.0	4.6	1.009	6	1.000	0	0	0.0
	3.7	6	3.7	1.006	6	1.000	0	0	0.0	3.8	1.019	6	1.000	0	0	0.0
neos-555771	3.8	6	3.7	0.985	6	1.000	0	0	0.0	4.1	*1.076*	6	1.000	0	0	0.0
	4.2	6	10.5	*2.185*	41	*1.330*	0	0	0.0	4.2	0.998	6	1.000	0	0	0.0
	3.1	6	3.2	1.007	6	1.000	0	0	0.0	3.2	1.012	6	1.000	0	0	0.0
	3.1	6	3.1	0.990	6	1.000	0	0	0.0	3.1	0.983	6	1.000	0	0	0.0
neos-555884	limit	659884	limit	1.000	651284	0.987	0	2620	155.4	limit	1.000	574424	**0.871**	0	4335	92.3
	limit	660539	limit	1.000	713985	*1.081*	0	2747	150.6	limit	1.000	790727	*1.197*	0	5357	108.7
	limit	714134	limit	1.000	763903	*1.070*	0	1976	164.4	limit	1.000	802513	*1.124*	0	7485	99.0
	limit	682004	limit	1.000	715418	1.049	0	4627	141.1	limit	1.000	715816	1.050	0	6328	104.4
neos-555927	limit	1707440	limit	1.000	1759692	1.031	0	31983	97.2	limit	1.000	1511523	**0.885**	0	9402	90.6
	limit	1884757	limit	1.000	1753634	**0.930**	0	34513	95.0	limit	1.000	1675846	**0.889**	0	11230	88.7
	limit	1505351	limit	1.000	1727969	*1.148*	0	13987	94.3	limit	1.000	1684911	*1.119*	0	5738	83.9
	limit	1729037	limit	1.000	1810226	1.047	0	8830	101.4	limit	1.000	1731024	1.001	0	8637	88.5
neos-565672	3740.3	35	3527.7	**0.943**	34	0.993	0	0	0.0	3606.2	0.964	21	**0.896**	0	0	0.0
	4551.6	6	5095.5	*1.119*	22	*1.151*	0	0	0.0	5665.0	*1.245*	40	*1.321*	0	0	0.0
	3975.2	10	3959.2	0.996	10	1.000	0	0	0.0	4022.2	1.012	10	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	5249.6	18	5148.3	0.981	20	1.017	0	0	0.0	5673.2	*1.081*	45	*1.229*	0	1	41.0
neos-565815	13.5	1	13.4	0.991	1	1.000	0	0	0.0	13.7	1.017	1	1.000	0	0	0.0
	14.4	1	14.4	0.996	1	1.000	0	0	0.0	14.6	1.007	1	1.000	0	0	0.0
	10.7	1	10.8	1.003	1	1.000	0	0	0.0	10.7	0.998	1	1.000	0	0	0.0
	12.3	1	12.2	0.998	1	1.000	0	0	0.0	12.2	0.995	1	1.000	0	0	0.0
neos-570431	12.9	327	12.6	0.979	277	**0.883**	0	10	90.0	15.6	*1.191*	417	*1.211*	0	12	30.0
	15.2	375	14.1	**0.930**	375	1.000	0	0	0.0	15.1	0.994	373	0.996	0	6	43.0
	12.6	293	12.4	0.990	285	0.980	0	0	0.0	13.4	*1.059*	361	*1.173*	0	0	35.0
	13.6	347	13.5	0.999	285	**0.861**	0	0	0.0	13.1	0.968	267	**0.821**	0	0	0.0
neos-574665	limit	9936179	limit	1.000	8759223	**0.882**	0	396	42.0	limit	1.000	9256586	**0.932**	0	334	35.2
	limit	7612103	limit	1.000	6004116	**0.789**	0	263	44.1	limit	1.000	6633237	**0.871**	0	184	39.2
	limit	6938581	limit	1.000	5345467	**0.770**	0	231	38.6	limit	1.000	6552313	**0.944**	0	128	36.7
	limit	6767736	limit	1.000	8163765	*1.206*	0	311	39.4	limit	1.000	7815923	*1.155*	0	77	36.6
neos-578379	221.0	1	221.4	1.002	1	1.000	0	0	0.0	220.6	0.998	1	1.000	0	0	0.0
	223.8	1	224.0	1.001	1	1.000	0	0	0.0	223.9	1.001	1	1.000	0	0	0.0
	235.4	3	235.7	1.001	3	1.000	0	0	0.0	235.6	1.001	3	1.000	0	0	0.0
	222.3	1	221.1	0.994	1	1.000	0	0	0.0	222.5	1.000	1	1.000	0	0	0.0
neos-582605	limit	1059514	limit	1.000	1080287	1.020	0	354	128.1	limit	1.000	887119	**0.837**	0	404	120.7
	limit	932645	limit	1.000	942324	1.010	0	316	129.8	limit	1.000	900289	0.965	0	264	131.2
	limit	994133	limit	1.000	1009924	1.016	0	269	126.6	limit	1.000	989997	0.996	0	314	128.5
	limit	1034396	limit	1.000	956019	**0.924**	0	195	135.3	limit	1.000	921904	**0.891**	0	366	120.0
neos-583731	11.7	29	11.8	1.015	29	1.000	0	0	0.0	12.1	1.034	29	1.000	0	0	0.0
	9.5	17	9.4	0.991	17	1.000	0	0	0.0	9.4	0.995	17	1.000	0	0	0.0
	15.4	42	15.5	1.006	42	1.000	0	0	0.0	15.5	1.007	42	1.000	0	0	0.0
	9.2	19	9.1	0.991	19	1.000	0	0	0.0	9.2	1.000	19	1.000	0	0	0.0
neos-584146	limit	1323112	limit	1.000	1634281	*1.235*	0	38	115.4	limit	1.000	1769849	*1.338*	0	484	98.2
	limit	1835270	limit	1.000	1797087	0.979	0	57	112.2	limit	1.000	1848803	1.007	0	611	94.1
	limit	1242980	limit	1.000	1227340	0.987	0	35	116.8	limit	1.000	1434564	*1.154*	0	316	96.2
	limit	1813463	limit	1.000	1981732	*1.093*	0	71	113.9	limit	1.000	1767071	0.974	0	211	107.7
neos-584851	9.9	7	9.9	1.004	7	1.000	0	0	0.0	9.9	1.003	7	1.000	0	0	0.0
	22.4	70	22.4	1.000	70	1.000	0	0	0.0	22.4	0.997	70	1.000	0	0	0.0
	18.0	7	18.0	1.003	7	1.000	0	0	0.0	18.1	1.005	7	1.000	0	0	0.0
	18.1	28	18.2	1.001	28	1.000	0	0	0.0	18.2	1.004	28	1.000	0	0	0.0
neos-584866	limit	189709	limit	1.000	193364	1.019	0	232	127.2	limit	1.000	180436	0.951	0	83	187.5
	limit	205018	limit	1.000	194889	0.951	0	24	195.0	limit	1.000	213061	1.039	0	444	189.5
	limit	229030	limit	1.000	194054	**0.847**	0	87	86.2	limit	1.000	225496	0.985	0	169	373.6

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	203326	limit	1.000	214239	*1.054*	0	0	100.7	limit	1.000	231699	*1.139*	0	470	168.5
neos-585192	21.3	406	21.5	1.007	406	1.000	0	0	0.0	21.2	0.994	406	1.000	0	0	0.0
	26.2	676	26.2	1.001	676	1.000	0	0	0.0	25.8	0.986	648	0.964	0	0	0.0
	25.1	359	25.2	1.001	359	1.000	0	0	0.0	25.1	0.998	359	1.000	0	0	0.0
	26.0	606	26.1	1.003	606	1.000	0	0	0.0	25.9	0.996	606	1.000	0	0	0.0
neos-585467	14.0	91	14.1	1.004	91	1.000	0	0	0.0	12.5	**0.902**	72	**0.901**	0	0	0.0
	12.5	93	12.5	1.001	93	1.000	0	0	0.0	12.5	0.998	93	1.000	0	0	0.0
	13.9	108	9.2	**0.683**	39	**0.668**	0	0	0.0	14.0	1.005	108	1.000	0	0	0.0
	11.9	89	11.9	1.004	89	1.000	0	0	0.0	11.9	0.998	89	1.000	0	0	0.0
neos-593853	455.6	213158	74.8	**0.166**	34081	**0.160**	2	159	36.2	64.3	**0.143**	28866	**0.136**	0	503	40.2
	159.8	54020	246.0	*1.536*	67870	*1.256*	1	153	41.7	55.5	**0.351**	18974	**0.352**	0	120	47.9
	71.9	20186	137.3	*1.898*	59663	*2.946*	0	160	45.4	175.9	*2.428*	58925	*2.910*	0	216	45.1
	78.8	27349	130.0	*1.642*	34312	*1.254*	0	130	39.7	66.0	**0.841**	22952	**0.840**	0	166	40.6
neos-595904	14.6	3	14.7	1.002	3	1.000	0	0	0.0	14.2	0.972	3	1.000	0	0	0.0
	24.3	4	24.1	0.994	4	1.000	0	0	0.0	24.2	0.995	4	1.000	0	0	0.0
	21.6	4	21.5	0.995	4	1.000	0	0	0.0	21.6	0.999	4	1.000	0	0	0.0
	24.8	5	26.4	*1.061*	5	1.000	0	0	0.0	24.8	0.999	5	1.000	0	0	0.0
neos-595905	2.4	2	2.5	*1.050*	2	1.000	0	0	0.0	2.5	1.045	2	1.000	0	0	0.0
	2.6	3	2.7	1.008	3	1.000	0	0	0.0	2.6	0.992	3	1.000	0	0	0.0
	1.8	2	1.9	1.011	2	1.000	0	0	0.0	1.9	1.011	2	1.000	0	0	0.0
	2.0	2	2.1	1.020	2	1.000	0	0	0.0	2.0	0.997	2	1.000	0	0	0.0
neos-595925	17.2	593	13.3	**0.783**	465	**0.815**	0	0	0.0	13.3	**0.783**	465	**0.815**	0	0	0.0
	20.1	791	27.3	*1.340*	1856	*2.195*	0	0	40.0	26.8	*1.319*	1241	*1.505*	0	131	15.0
	33.9	1970	13.7	**0.421**	262	**0.175**	0	0	0.0	14.9	**0.455**	336	**0.211**	0	0	0.0
	19.8	363	19.8	1.000	363	1.000	0	0	0.0	13.5	**0.700**	130	**0.497**	0	0	0.0
neos-598183	8.4	6	6.9	**0.838**	4	0.981	0	0	0.0	8.1	0.962	5	0.991	0	0	0.0
	6.4	9	9.0	*1.345*	6	0.972	0	0	0.0	8.8	*1.316*	5	0.963	0	0	0.0
	8.7	11	8.3	0.961	11	1.000	0	0	0.0	6.4	**0.771**	45	*1.306*	0	0	15.0
	6.6	20	7.7	*1.138*	7	**0.892**	0	0	0.0	7.9	*1.171*	4	**0.867**	0	0	0.0
neos-603073	6855.4	1457555	193.4	**0.028**	37727	**0.026**	0	0	43.7	171.2	**0.025**	19608	**0.014**	0	32	51.0
	745.9	170233	312.3	**0.419**	46627	**0.274**	0	19	48.5	251.2	**0.338**	43774	**0.258**	0	14	43.0
	115.7	13204	limit	*61.684*	1918916	*144.244*	0	38	52.9	166.2	*1.432*	23050	*1.740*	0	39	37.3
	556.2	88538	224.8	**0.405**	32941	**0.373**	0	14	56.6	limit	*12.924*	1652722	*18.647*	0	42	48.2
neos-611135	limit	162781	limit	1.000	207112	*1.272*	0	1055	39.8	limit	1.000	157797	0.969	0	439	44.4
	limit	174965	limit	1.000	160153	**0.915**	0	616	94.9	limit	1.000	150091	**0.858**	1	469	57.3
	limit	164893	limit	1.000	146325	**0.887**	1	351	50.5	limit	1.000	160277	0.972	0	572	74.9

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Table D.2: Computational results on MMMC: CONFLICT DIVING

	nolockdiving		coefdiving						confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	121174	limit	1.000	128697	*1.062*	0	698	61.3	limit	1.000	136600	*1.127*	0	945	66.2
neos-611838	41.5	241	36.7	**0.889**	282	*1.120*	0	0	26.0	36.2	**0.876**	282	*1.120*	0	0	26.0
	40.4	319	40.1	0.992	319	1.000	0	0	25.0	40.2	0.995	319	1.000	0	0	25.0
	34.0	251	33.5	0.987	272	*1.060*	0	0	20.5	33.6	0.989	272	*1.060*	0	0	20.5
	37.6	210	38.6	1.027	210	1.000	0	0	18.0	37.5	0.999	210	1.000	0	0	0.0
neos-612125	26.6	45	27.7	1.039	45	1.000	0	0	23.0	26.3	0.989	45	1.000	0	0	23.0
	31.1	154	31.1	1.000	154	1.000	0	0	23.0	31.2	1.003	154	1.000	0	0	23.0
	31.3	175	31.4	1.004	175	1.000	0	0	20.0	31.5	1.007	175	1.000	0	0	20.0
	28.8	161	29.1	1.010	161	1.000	0	0	31.0	28.8	0.999	161	1.000	0	0	31.0
neos-612143	35.9	213	36.6	1.019	203	0.968	0	0	28.0	36.7	1.023	213	1.000	0	0	28.0
	32.2	172	32.8	1.018	177	1.018	0	0	25.0	33.0	1.022	177	1.018	0	0	25.0
	42.5	170	43.9	1.033	170	1.000	0	0	26.0	43.9	1.032	170	1.000	0	0	26.0
	39.0	302	39.1	1.003	302	1.000	0	0	29.0	39.3	1.006	302	1.000	0	0	29.0
neos-612162	37.4	197	34.6	**0.926**	197	1.000	0	0	14.0	34.4	**0.921**	197	1.000	0	0	14.0
	37.1	184	37.1	1.001	184	1.000	0	0	25.0	37.4	1.008	184	1.000	0	0	25.0
	28.9	219	29.2	1.008	219	1.000	0	0	23.0	29.1	1.005	219	1.000	0	0	23.0
	34.5	265	33.9	0.984	265	1.000	0	0	27.0	33.9	0.984	265	1.000	0	0	27.0
neos-619167	limit	100	limit	1.000	161	*1.305*	0	9	80.0	limit	1.000	69	**0.845**	0	2	166.0
	limit	148	limit	1.000	148	1.000	0	0	0.0	limit	1.000	148	1.000	0	0	0.0
	limit	54	limit	1.000	107	*1.344*	0	3	93.0	limit	1.000	167	*1.734*	0	2	158.0
	limit	102	limit	1.000	102	1.000	0	0	0.0	limit	1.000	102	1.000	0	0	0.0
neos-631164	limit	323115	limit	1.000	408802	*1.265*	0	0	213.3	limit	1.000	371492	*1.150*	0	0	255.7
	limit	213333	limit	1.000	224576	*1.053*	0	0	250.2	limit	1.000	359413	*1.684*	0	0	258.4
	limit	460027	limit	1.000	426195	**0.926**	0	31	215.0	limit	1.000	534245	*1.161*	0	0	242.3
	limit	517751	limit	1.000	320508	**0.619**	0	26	236.3	limit	1.000	549421	*1.061*	0	55	223.2
neos-631517	limit	803071	limit	1.000	383942	**0.478**	0	0	225.0	limit	1.000	658819	**0.820**	0	0	247.0
	limit	361289	limit	1.000	414404	*1.147*	0	0	215.0	limit	1.000	392674	*1.087*	0	0	240.5
	limit	351827	limit	1.000	647686	*1.841*	0	11	209.2	limit	1.000	307236	**0.873**	0	0	242.6
	limit	627858	limit	1.000	473556	**0.754**	0	0	224.2	limit	1.000	654293	1.042	0	0	259.6
neos-631694	limit	675050	limit	1.000	700417	1.038	0	1113	125.3	limit	1.000	706702	1.047	0	3444	98.9
	limit	675799	limit	1.000	474828	**0.703**	0	653	131.8	limit	1.000	504509	**0.747**	0	2655	83.0
	limit	568437	300.9	**0.042**	8911	**0.016**	0	147	189.9	limit	1.000	502345	**0.884**	0	2859	89.3
	limit	706590	limit	1.000	819670	*1.160*	0	532	134.0	limit	1.000	850369	*1.203*	0	3654	89.9
neos-631709	limit	3864	limit	1.000	4252	*1.098*	0	0	649.5	limit	1.000	3152	**0.820**	0	0	119.5
	limit	700	limit	1.000	443	**0.679**	0	0	520.0	limit	1.000	492	**0.740**	0	150	84.5
	limit	263	limit	1.000	260	0.992	0	0	465.0	limit	1.000	227	**0.901**	0	0	102.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	155	limit	1.000	128	**0.894**	0	0	426.0	limit	1.000	159	1.016	0	193	86.0
neos-631710	limit	1	limit	1.000	1	1.000	0	0	0.0	limit	1.000	1	1.000	0	0	0.0
	limit	3	limit	1.000	3	1.000	0	0	0.0	limit	1.000	3	1.000	0	0	0.0
	limit	1	limit	1.000	1	1.000	0	0	0.0	limit	1.000	1	1.000	0	0	0.0
	limit	1	limit	1.000	1	1.000	0	0	0.0	limit	1.000	1	1.000	0	0	0.0
neos-631784	4226.3	154351	limit	*1.703*	168015	*1.088*	0	189	257.3	limit	*1.703*	286725	*1.857*	0	8590	84.6
	1597.5	58460	2854.0	*1.786*	82947	*1.418*	0	237	287.8	1703.6	*1.066*	47570	**0.814**	0	2583	83.6
	limit	404754	limit	1.000	288158	**0.712**	1	1046	167.7	limit	1.000	331961	**0.820**	0	15363	80.7
	4420.3	145938	5000.6	*1.131*	159799	*1.095*	0	316	183.7	5334.4	*1.207*	204465	*1.401*	0	3844	88.0
neos-632335	13.6	193	13.5	0.990	193	1.000	0	0	0.0	13.5	0.996	193	1.000	0	0	0.0
	13.3	193	13.4	1.003	193	1.000	0	0	0.0	13.3	0.994	193	1.000	0	0	0.0
	13.3	193	13.3	1.002	193	1.000	0	0	0.0	13.3	1.001	193	1.000	0	0	0.0
	13.6	197	13.5	0.992	197	1.000	0	0	0.0	13.6	1.003	197	1.000	0	0	0.0
neos-633273	14.2	259	14.2	0.995	259	1.000	0	0	0.0	14.2	0.999	259	1.000	0	0	0.0
	13.9	259	13.9	1.001	259	1.000	0	0	0.0	14.1	1.009	259	1.000	0	0	0.0
	13.7	253	13.6	0.995	253	1.000	0	0	0.0	13.7	0.999	253	1.000	0	0	0.0
	13.9	259	14.0	1.006	259	1.000	0	0	0.0	13.9	0.999	259	1.000	0	0	0.0
neos-655508	0.6	1	0.6	0.957	1	1.000	0	0	0.0	0.7	1.030	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
neos-662469	limit	56606	limit	1.000	20973	**0.372**	1	695	111.3	limit	1.000	35231	**0.623**	0	182	278.1
	limit	47738	limit	1.000	33181	**0.696**	0	414	109.2	limit	1.000	23154	**0.486**	0	314	246.6
	limit	53221	limit	1.000	64928	*1.220*	1	1095	129.5	limit	1.000	45010	**0.846**	0	904	265.6
	limit	32406	limit	1.000	21646	**0.669**	2	1533	132.0	limit	1.000	36531	*1.127*	0	247	291.7
neos-686190	206.9	13509	124.2	**0.602**	5703	**0.426**	0	569	36.0	113.7	**0.552**	4657	**0.350**	0	142	38.5
	197.9	11514	203.2	1.027	13529	*1.173*	0	132	38.2	122.1	**0.619**	6495	**0.568**	0	89	39.3
	145.9	8789	159.9	*1.095*	8992	1.023	0	474	40.0	137.6	**0.944**	8222	**0.936**	0	213	34.8
	190.8	11046	324.7	*1.699*	21982	*1.981*	0	2562	41.1	127.4	**0.669**	6798	**0.619**	0	197	33.1
neos-691058	limit	6179	limit	1.000	4407	**0.718**	0	55	264.1	limit	1.000	4322	**0.704**	0	81	79.2
	limit	4906	limit	1.000	5899	*1.198*	0	9	309.9	limit	1.000	5515	*1.122*	0	11	179.8
	limit	7229	limit	1.000	9326	*1.286*	0	53	254.8	limit	1.000	23983	*3.286*	0	259	94.7
	limit	5929	limit	1.000	4485	**0.760**	0	28	281.3	limit	1.000	5128	**0.867**	0	170	87.8
neos-691073	limit	13845	limit	1.000	19895	*1.434*	0	94	256.9	limit	1.000	8723	**0.633**	0	45	112.7
	limit	22067	limit	1.000	11181	**0.509**	0	26	270.4	limit	1.000	11460	**0.521**	0	105	90.8
	limit	10232	limit	1.000	8799	**0.861**	0	62	184.2	limit	1.000	10122	0.989	0	58	71.7

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	7700	limit	1.000	8946	*1.160*	0	108	240.6	limit	1.000	8258	*1.072*	1	223	94.9
neos-693347	limit	55024	1734.2	**0.241**	12433	**0.227**	0	128	136.5	1861.5	**0.259**	8535	**0.157**	0	2544	55.7
	2238.8	17100	2356.6	*1.053*	17666	1.033	0	4621	65.0	1858.2	**0.830**	15792	**0.924**	0	1035	47.3
	5122.1	31274	7053.2	*1.377*	74565	*2.380*	0	1716	66.4	2814.4	**0.550**	10210	**0.329**	0	789	54.7
	4900.7	34909	4295.3	**0.876**	46192	*1.322*	0	495	69.5	2443.8	**0.499**	15087	**0.434**	0	3126	46.4
neos-702280	limit	3798	limit	1.000	3728	0.982	0	0	399.8	limit	1.000	3929	1.034	0	0	387.0
	limit	3731	limit	1.000	3435	**0.923**	0	0	397.2	limit	1.000	3495	**0.938**	0	0	397.2
	limit	3958	limit	1.000	3703	**0.937**	0	0	411.2	limit	1.000	3776	0.955	0	0	417.8
	limit	4210	limit	1.000	3833	**0.913**	0	0	409.0	limit	1.000	3748	**0.893**	0	0	412.5
neos-709469	0.5	13	0.6	*1.093*	13	1.000	0	0	0.0	0.5	1.000	13	1.000	0	0	0.0
	0.7	99	0.9	*1.145*	377	*2.397*	0	6	26.0	1.4	*1.461*	1433	*7.704*	0	58	32.5
	0.6	120	0.6	0.988	120	1.000	0	0	0.0	0.6	0.994	120	1.000	0	0	0.0
	0.8	240	0.8	1.023	315	*1.221*	0	3	34.0	0.6	**0.886**	68	**0.494**	0	4	30.0
neos-717614	16.2	4611	26.7	*1.611*	7251	*1.560*	0	4	132.7	36.0	*2.153*	18882	*4.029*	0	13	450.5
	15.2	2169	44.5	*2.802*	19659	*8.708*	0	2	225.5	19.5	*1.264*	4136	*1.867*	0	14	84.2
	60.3	35953	4321.0	*70.471*	1782616	*49.447*	0	4	326.3	15.4	**0.267**	1858	**0.054**	0	16	74.1
	50.8	24048	58.3	*1.146*	38062	*1.580*	0	12	107.4	48.0	**0.946**	30789	*1.279*	0	7	141.3
neos-738098	limit	727	limit	1.000	532	**0.764**	0	24	383.7	limit	1.000	563	**0.802**	0	188	111.3
	limit	254	limit	1.000	261	1.020	0	0	156.0	limit	1.000	596	*1.966*	0	254	166.0
	limit	413	limit	1.000	378	**0.932**	0	194	306.7	limit	1.000	447	*1.066*	0	68	127.0
	limit	1416	limit	1.000	663	**0.503**	0	79	383.2	limit	1.000	735	**0.551**	0	138	120.0
neos-775946	9.3	5	9.9	*1.064*	4	0.990	0	0	0.0	12.4	*1.304*	5	1.000	0	0	0.0
	16.4	44	16.6	1.007	44	1.000	0	0	0.0	14.9	**0.913**	28	**0.889**	0	0	0.0
	8.3	3	12.2	*1.428*	3	1.000	0	0	0.0	12.6	*1.468*	13	*1.097*	0	0	0.0
	12.1	5	9.8	**0.823**	4	0.990	0	0	0.0	9.5	**0.802**	7	1.019	0	0	0.0
neos-780889	359.6	2	361.5	1.005	2	1.000	0	0	0.0	359.7	1.000	2	1.000	0	0	0.0
	62.5	1	62.6	1.001	1	1.000	0	0	0.0	62.7	1.003	1	1.000	0	0	0.0
	53.3	1	53.5	1.004	1	1.000	0	0	0.0	54.3	1.019	1	1.000	0	0	0.0
	57.0	1	53.8	**0.946**	1	1.000	0	0	0.0	54.1	0.951	1	1.000	0	0	0.0
neos-785899	3.1	22	2.9	**0.949**	22	1.000	0	0	0.0	2.9	0.954	22	1.000	0	0	0.0
	5.6	35	5.6	1.011	35	1.000	0	0	0.0	5.6	1.006	35	1.000	0	0	0.0
	4.7	39	4.6	0.996	39	1.000	0	0	0.0	4.7	1.014	39	1.000	0	0	0.0
	3.6	37	3.5	0.991	37	1.000	0	0	0.0	3.5	0.993	37	1.000	0	0	0.0
neos-785912	53.9	384	54.0	1.001	384	1.000	0	0	0.0	54.5	1.011	384	1.000	0	0	0.0
	44.9	227	44.7	0.997	227	1.000	0	0	0.0	44.9	1.001	227	1.000	0	0	0.0
	46.4	331	46.8	1.009	331	1.000	0	0	0.0	46.2	0.997	331	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	95.8	264	100.7	1.050	290	*1.071*	0	11	325.0	102.7	*1.071*	306	*1.115*	0	19	21.0
neos-785914	11.1	16	11.2	1.007	16	1.000	0	0	0.0	11.4	1.023	16	1.000	0	0	0.0
	11.4	14	11.1	0.978	14	1.000	0	0	0.0	11.3	0.990	14	1.000	0	0	0.0
	6.3	16	6.3	1.000	16	1.000	0	0	0.0	6.3	0.995	16	1.000	0	0	0.0
	7.1	18	7.0	0.990	18	1.000	0	0	0.0	7.0	0.988	18	1.000	0	0	0.0
neos-787933	1.6	1	1.6	0.996	1	1.000	0	0	0.0	1.6	0.977	1	1.000	0	0	0.0
	1.6	1	1.6	1.000	1	1.000	0	0	0.0	1.6	1.004	1	1.000	0	0	0.0
	1.6	1	1.6	0.992	1	1.000	0	0	0.0	1.7	1.027	1	1.000	0	0	0.0
	1.6	1	1.6	1.004	1	1.000	0	0	0.0	1.6	1.008	1	1.000	0	0	0.0
neos-791021	585.4	95	517.1	**0.884**	89	0.969	0	18	291.0	641.9	*1.096*	127	*1.164*	0	3	18.0
	479.5	66	473.9	0.988	91	*1.151*	0	9	438.0	487.7	1.017	66	1.000	0	0	0.0
	436.5	60	359.0	**0.823**	47	**0.919**	0	0	263.0	439.8	1.008	68	*1.050*	0	0	26.0
	645.2	120	524.8	**0.814**	81	**0.823**	0	5	293.0	745.1	*1.155*	121	1.005	0	4	45.0
neos-796608	251.8	843587	262.9	1.044	864703	1.025	0	13	23.2	258.4	1.026	864751	1.025	0	18	24.5
	257.2	841119	257.3	1.000	843360	1.003	0	37	22.9	260.1	1.011	854539	1.016	0	11	20.2
	0.5	2	0.5	1.000	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0
	255.0	861013	252.4	0.990	848510	0.985	0	66	22.7	252.0	0.988	843913	0.980	0	74	22.5
neos-799838	41.5	1	42.1	1.014	1	1.000	0	0	0.0	41.5	1.000	1	1.000	0	0	0.0
	32.8	1	32.5	0.991	1	1.000	0	0	0.0	32.7	0.998	1	1.000	0	0	0.0
	121.9	10	121.8	0.999	10	1.000	0	0	0.0	122.2	1.002	10	1.000	0	0	0.0
	33.6	1	33.4	0.995	1	1.000	0	0	0.0	33.4	0.995	1	1.000	0	0	0.0
neos-801834	52.0	159	52.4	1.007	159	1.000	0	0	0.0	51.5	0.991	159	1.000	0	0	0.0
	50.5	175	49.9	0.989	175	1.000	0	0	0.0	50.5	1.000	175	1.000	0	0	0.0
	60.3	217	60.0	0.995	217	1.000	0	0	0.0	60.5	1.004	217	1.000	0	0	0.0
	44.4	155	44.8	1.009	155	1.000	0	0	0.0	44.1	0.995	155	1.000	0	0	0.0
neos-803219	39.9	11596	50.0	*1.246*	13044	*1.124*	0	342	23.4	45.2	*1.131*	11433	0.986	0	369	23.7
	48.8	13052	41.3	**0.851**	10451	**0.802**	1	304	20.9	53.1	*1.087*	14339	*1.098*	0	496	23.2
	47.2	13060	36.1	**0.771**	11087	**0.850**	0	143	25.5	36.2	**0.773**	10272	**0.788**	0	226	21.4
	32.7	8341	38.9	*1.185*	9805	*1.173*	0	295	23.9	42.5	*1.293*	11541	*1.379*	0	322	21.9
neos-803220	109.2	47940	109.6	1.004	46306	0.966	1	758	24.0	108.2	0.991	46456	0.969	0	444	24.2
	99.0	43166	99.5	1.004	41753	0.967	1	760	24.1	109.3	*1.103*	47046	*1.090*	0	465	23.1
	94.5	41738	87.9	**0.931**	38753	**0.929**	0	508	23.8	102.6	*1.085*	43146	1.034	5	966	25.9
	97.9	42934	104.9	*1.070*	43474	1.013	3	1003	25.6	98.4	1.005	41075	0.957	2	898	25.1
neos-806323	40.3	5993	42.1	1.044	5789	0.967	1	498	21.3	41.7	1.034	5886	0.982	1	510	21.0
	52.3	8199	56.1	*1.072*	9542	*1.162*	0	281	20.8	51.0	0.976	7878	0.961	0	183	28.6
	47.0	6985	47.9	1.019	7845	*1.121*	0	410	23.9	40.4	**0.863**	5727	**0.822**	0	123	27.2

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	47.5	8553	45.9	0.968	7734	**0.905**	0	281	22.0	42.1	**0.889**	6935	**0.813**	0	179	24.7
neos-807454	3.1	1	3.2	1.032	1	1.000	0	0	0.0	3.2	1.029	1	1.000	0	0	0.0
	3.1	1	3.1	0.993	1	1.000	0	0	0.0	3.0	0.988	1	1.000	0	0	0.0
	3.0	1	2.9	0.982	1	1.000	0	0	0.0	2.9	0.987	1	1.000	0	0	0.0
	2.5	1	2.5	0.986	1	1.000	0	0	0.0	2.5	0.994	1	1.000	0	0	0.0
neos-807639	22.1	2750	23.2	1.049	2824	1.026	0	399	15.2	22.2	1.007	2611	0.951	0	303	15.3
	23.2	2615	22.8	0.984	2595	0.993	0	365	15.6	22.7	0.978	2630	1.006	0	327	14.7
	17.2	1930	21.7	*1.246*	2501	*1.281*	0	307	16.3	19.8	*1.142*	2196	*1.131*	0	260	14.6
	24.0	2838	24.4	1.016	2933	1.032	0	352	16.4	24.6	1.024	2944	1.036	0	398	15.4
neos-807705	33.6	3595	38.0	*1.128*	3259	**0.909**	0	145	24.4	32.1	0.957	2977	**0.833**	0	155	19.9
	40.8	3291	49.7	*1.214*	4408	*1.329*	1	283	21.6	34.9	**0.859**	3132	0.953	0	181	20.1
	32.7	3490	36.3	*1.105*	3762	*1.076*	0	95	22.1	41.0	*1.246*	3753	*1.073*	1	247	21.0
	36.2	3871	37.5	1.036	3708	0.959	2	366	25.2	32.1	**0.891**	2775	**0.724**	1	327	18.6
neos-808072	41.4	334	34.6	**0.840**	411	*1.177*	0	0	127.0	46.0	*1.107*	308	**0.940**	0	246	56.0
	24.3	85	36.3	*1.475*	235	*1.811*	0	6	154.0	22.3	**0.921**	62	**0.876**	0	21	45.0
	20.7	59	20.6	0.998	59	1.000	0	0	0.0	20.7	1.002	59	1.000	0	0	0.0
	26.6	176	26.0	0.979	176	1.000	0	0	0.0	26.0	0.978	176	1.000	0	0	0.0
neos-808214	27.9	1091	29.5	*1.054*	902	**0.841**	0	102	117.0	26.4	**0.948**	793	**0.750**	0	245	40.5
	23.7	854	22.6	0.956	836	0.981	0	86	122.0	28.3	*1.187*	1375	*1.546*	0	217	37.8
	21.1	500	21.4	1.016	581	*1.135*	0	6	168.0	22.5	*1.064*	605	*1.175*	0	2	37.0
	32.5	1192	28.7	**0.886**	1488	*1.229*	0	118	127.0	28.9	**0.893**	1467	*1.213*	0	91	79.2
neos-810286	26.0	5	26.8	1.030	5	1.000	0	0	0.0	26.1	1.001	5	1.000	0	0	0.0
	312.4	745	279.1	**0.894**	474	**0.679**	0	36	354.5	110.4	**0.356**	61	**0.191**	0	0	15.0
	313.1	575	373.5	*1.192*	781	*1.305*	0	56	237.8	275.8	**0.881**	473	**0.849**	0	287	60.7
	159.4	362	305.8	*1.913*	1026	*2.437*	0	584	256.2	356.9	*2.231*	784	*1.913*	0	292	76.8
neos-810326	57.3	864	67.5	*1.175*	1196	*1.344*	0	20	59.7	48.8	**0.854**	853	0.989	1	79	73.1
	20.1	177	20.0	0.997	177	1.000	0	0	0.0	20.0	0.997	177	1.000	0	0	0.0
	49.4	765	47.8	0.967	851	*1.099*	0	144	76.9	40.3	**0.820**	640	**0.855**	0	64	37.0
	58.1	945	51.2	**0.884**	882	**0.940**	0	103	73.6	84.1	*1.440*	1551	*1.580*	0	158	53.2
neos-820146	limit	1780665	limit	1.000	1732674	0.973	0	31671	35.3	limit	1.000	1629186	**0.915**	0	38327	35.9
	limit	1650897	limit	1.000	1201855	**0.728**	0	21839	34.7	limit	1.000	2416318	*1.464*	0	34654	37.5
	limit	2728646	limit	1.000	2598857	0.952	0	40856	35.6	limit	1.000	2257699	**0.827**	0	42338	37.3
	limit	2189111	limit	1.000	2007483	**0.917**	0	49727	36.0	limit	1.000	2205407	1.007	0	51545	37.9
neos-820157	limit	1888549	limit	1.000	1552521	**0.822**	0	42382	34.9	limit	1.000	1587072	**0.840**	0	49625	35.3
	limit	1731099	limit	1.000	1663695	0.961	0	55339	36.0	limit	1.000	1616913	**0.934**	0	46602	35.1
	limit	1502000	limit	1.000	1298681	**0.865**	0	41409	35.2	limit	1.000	1737485	*1.157*	0	37876	36.4

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	1851270	limit	1.000	1911218	1.032	0	53628	34.6	limit	1.000	2095346	*1.132*	0	42615	35.5
neos-820879	51.7	393	62.1	*1.197*	31	**0.266**	0	0	0.0	79.2	*1.522*	411	1.037	0	0	0.0
	56.1	27	64.1	*1.140*	411	*4.024*	0	0	0.0	63.6	*1.132*	383	*3.803*	0	0	0.0
	52.0	32	52.2	1.004	32	1.000	0	0	0.0	51.9	0.998	32	1.000	0	0	0.0
	69.7	205	69.6	0.999	205	1.000	0	0	0.0	69.6	0.999	205	1.000	0	0	0.0
neos-824661	1229.9	87	1329.2	*1.081*	46	**0.781**	0	9	373.0	1228.4	0.999	62	**0.866**	0	0	0.0
	945.7	25	1027.7	*1.087*	37	*1.096*	0	16	462.0	1167.4	*1.234*	68	*1.344*	0	14	153.0
	1120.7	33	1228.1	*1.096*	85	*1.391*	0	3	441.0	1189.7	*1.062*	71	*1.286*	0	29	135.0
	1848.1	42	1884.7	1.020	43	1.007	0	0	348.0	1900.5	1.028	39	0.979	0	5	109.0
neos-824695	435.8	41	650.6	*1.492*	67	*1.184*	0	0	491.0	481.1	*1.104*	47	1.043	0	22	116.0
	599.4	98	357.9	**0.598**	31	**0.662**	0	0	314.0	431.1	**0.720**	26	**0.636**	1	9	135.0
	392.8	31	512.4	*1.304*	37	1.046	0	0	144.0	398.1	1.013	79	*1.366*	0	72	91.0
	416.5	31	319.6	**0.768**	19	**0.908**	0	0	189.0	394.2	**0.946**	28	0.977	0	0	62.0
neos-825075	2.0	1	1.5	**0.841**	1	1.000	0	0	0.0	2.0	0.993	1	1.000	0	0	0.0
	2.4	7	2.5	1.018	7	1.000	0	0	0.0	2.4	1.006	7	1.000	0	0	0.0
	2.4	5	2.4	1.018	5	1.000	0	0	0.0	2.4	1.003	5	1.000	0	0	0.0
	2.6	6	2.7	1.016	6	1.000	0	0	0.0	2.7	1.008	6	1.000	0	0	0.0
neos-826224	84.3	1	86.0	1.021	1	1.000	0	0	0.0	84.3	1.001	1	1.000	0	0	0.0
	235.1	35	288.4	*1.226*	45	*1.074*	0	0	342.0	364.8	*1.549*	26	**0.933**	0	29	362.0
	19.5	1	19.5	0.998	1	1.000	0	0	0.0	19.5	0.999	1	1.000	0	0	0.0
	13.2	1	13.2	0.996	1	1.000	0	0	0.0	13.3	1.008	1	1.000	0	0	0.0
neos-826250	229.9	24	210.3	**0.915**	18	0.952	0	0	403.0	210.8	**0.917**	18	0.952	0	0	75.0
	253.2	26	266.8	*1.053*	24	0.984	0	0	334.0	296.6	*1.171*	28	1.016	0	0	67.0
	50.1	1	49.7	0.992	1	1.000	0	0	0.0	344.4	*6.766*	32	*1.307*	0	0	74.0
	220.8	41	221.3	1.002	41	1.000	0	0	0.0	221.9	1.005	41	1.000	0	0	0.0
neos-826650	limit	17212	limit	1.000	27954	*1.620*	0	234	266.3	limit	1.000	25126	*1.457*	0	654	122.7
	limit	63302	limit	1.000	40743	**0.644**	0	520	213.2	limit	1.000	45266	**0.716**	0	771	216.2
	limit	15524	limit	1.000	13471	**0.869**	0	831	267.9	limit	1.000	16022	1.032	0	681	175.5
	limit	26608	limit	1.000	45403	*1.704*	0	465	265.4	limit	1.000	21687	**0.816**	0	350	182.6
neos-826694	367.3	64	274.2	**0.747**	24	**0.756**	0	0	0.0	275.6	**0.751**	24	**0.756**	0	0	0.0
	335.9	41	499.9	*1.487*	57	*1.113*	0	0	727.0	368.7	*1.097*	57	*1.113*	0	2	109.0
	426.4	77	534.9	*1.254*	201	*1.701*	0	0	0.0	533.6	*1.251*	201	*1.701*	0	0	0.0
	258.4	34	328.2	*1.269*	71	*1.276*	0	0	727.0	320.3	*1.239*	74	*1.299*	0	0	667.0
neos-826812	33.0	1	32.4	0.982	1	1.000	0	0	0.0	32.2	0.978	1	1.000	0	0	0.0
	55.3	1	249.6	*4.450*	18	*1.168*	0	0	206.0	354.2	*6.308*	38	*1.366*	0	0	121.0
	156.7	5	156.8	1.001	5	1.000	0	0	0.0	157.3	1.004	5	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: CONFLICT DIVING

Instance	nolockdiving		coefdiving							confdiving						
	T	**N**	**T**	**TQ**	**N**	**NQ**	**F**	**C**	**D∅**	**T**	**TQ**	**N**	**NQ**	**F**	**C**	**D∅**
	172.5	6	252.9	*1.463*	7	1.009	0	0	0.0	172.5	1.000	6	1.000	0	0	0.0
neos-826841	limit	131065	limit	1.000	181273	*1.383*	0	509	210.8	limit	1.000	156159	*1.191*	0	865	76.7
	limit	162202	limit	1.000	103819	**0.640**	0	705	170.5	limit	1.000	108936	**0.672**	0	1756	82.5
	limit	164972	limit	1.000	123409	**0.748**	0	276	249.1	limit	1.000	206451	*1.251*	0	1552	100.9
	limit	297953	limit	1.000	108801	**0.365**	0	599	180.7	limit	1.000	133860	**0.449**	0	976	82.3
neos-827015	1312.8	357	1492.8	*1.137*	337	0.956	0	86	72.0	1091.9	**0.832**	235	**0.733**	0	25	44.5
	1038.0	252	1473.0	*1.419*	301	*1.139*	0	126	107.8	1259.5	*1.213*	180	**0.795**	0	34	32.7
	2067.0	304	3856.2	*1.865*	924	*2.535*	1	112	65.3	1342.9	**0.650**	251	**0.869**	0	7	25.0
	1027.1	213	848.4	**0.826**	174	**0.875**	0	32	132.5	1201.7	*1.170*	284	*1.227*	0	108	36.8
neos-827175	7.6	1	7.3	0.967	1	1.000	0	0	0.0	7.3	0.971	1	1.000	0	0	0.0
	9.9	1	9.9	1.001	1	1.000	0	0	0.0	9.9	0.997	1	1.000	0	0	0.0
	8.0	1	8.1	1.008	1	1.000	0	0	0.0	8.1	1.012	1	1.000	0	0	0.0
	40.0	1	40.2	1.004	1	1.000	0	0	0.0	40.1	1.002	1	1.000	0	0	0.0
neos-829552	347.8	244	313.3	**0.901**	179	**0.811**	0	1	95.0	336.7	0.968	164	**0.767**	0	0	37.0
	565.4	510	327.6	**0.580**	249	**0.572**	0	30	70.0	277.4	**0.491**	142	**0.397**	1	0	29.0
	413.5	268	331.8	**0.803**	230	**0.897**	0	30	49.0	353.1	**0.854**	258	0.973	1	0	30.0
	405.6	332	472.5	*1.164*	419	*1.201*	0	61	78.3	487.3	*1.201*	349	1.039	0	35	34.0
neos-830439	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
neos-831188	245.3	1813	319.2	*1.300*	2585	*1.404*	0	298	61.9	241.2	0.983	1666	**0.923**	0	53	31.5
	327.3	2365	354.4	*1.083*	2749	*1.156*	0	528	42.2	270.2	**0.826**	2025	**0.862**	0	98	28.7
	294.0	2396	407.3	*1.384*	3119	*1.290*	0	280	59.2	330.9	*1.125*	2320	0.970	0	59	28.0
	336.9	2683	388.7	*1.154*	2773	1.032	0	595	49.2	343.9	1.021	2754	1.026	0	140	34.0
neos-839838	3102.5	106988	1865.2	**0.601**	55355	**0.518**	0	70	86.6	831.7	**0.268**	19434	**0.182**	0	71	79.5
	1099.9	28382	1174.7	*1.068*	35500	*1.250*	0	0	78.6	1141.0	1.037	27895	0.983	0	0	73.0
	738.1	15857	1691.1	*2.289*	45773	*2.875*	0	33	72.2	1041.3	*1.410*	25840	*1.626*	0	7	82.0
	1320.6	44833	910.6	**0.690**	26284	**0.587**	2	142	81.5	1432.2	*1.084*	42461	**0.947**	0	0	82.6
neos-839859	52.7	2140	51.5	0.977	1834	**0.863**	0	0	48.0	51.8	0.984	1834	**0.863**	0	0	55.0
	54.3	2493	56.9	1.047	2550	1.022	0	15	47.5	53.6	0.988	2354	**0.946**	0	0	39.0
	58.3	2565	59.8	1.024	2538	0.990	0	0	56.0	59.7	1.023	2538	0.990	0	14	42.5
	57.3	2354	86.4	*1.499*	4753	*1.978*	0	4	32.7	69.6	*1.211*	3492	*1.464*	0	14	43.2
neos-839894	limit	200	limit	1.000	139	**0.797**	0	0	19.0	limit	1.000	244	*1.147*	0	87	70.5
	limit	236	limit	1.000	137	**0.705**	0	0	22.0	limit	1.000	676	*2.310*	0	0	93.0
	limit	170	limit	1.000	147	**0.915**	0	0	12.0	limit	1.000	55	**0.574**	0	24	36.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	324	limit	1.000	123	**0.526**	0	0	48.0	limit	1.000	435	*1.262*	0	40	80.0
neos-841664	limit	65663	limit	1.000	71284	*1.085*	4	200	78.7	limit	1.000	119949	*1.825*	5	1276	74.7
	3312.8	30581	limit	*2.173*	102166	*3.333*	0	55	61.1	limit	*2.173*	56229	*1.836*	6	252	94.9
	limit	89023	3668.7	**0.510**	45747	**0.514**	0	85	71.3	limit	1.000	141483	*1.589*	2	451	80.1
	limit	58603	limit	1.000	61327	1.046	3	135	75.2	limit	1.000	72314	*1.234*	3	240	83.6
neos-847051	limit	2403164	limit	1.000	1941245	**0.808**	1	1	72.4	limit	1.000	2021897	**0.841**	0	0	61.9
	3693.6	1209906	limit	*1.949*	2104682	*1.739*	0	41	38.2	4256.5	*1.152*	1442266	*1.192*	0	50	29.7
	limit	2326051	limit	1.000	1010762	**0.435**	0	27	32.0	limit	1.000	1945762	**0.837**	0	21	31.8
	limit	2259979	limit	1.000	2492817	*1.103*	0	0	40.8	limit	1.000	2156972	0.954	0	1	35.5
neos-847302	limit	230337	limit	1.000	219054	0.951	0	63	81.7	limit	1.000	257418	*1.118*	0	310	60.1
	limit	189560	limit	1.000	203966	*1.076*	0	54	87.2	limit	1.000	188202	0.993	0	121	81.8
	limit	179917	limit	1.000	192625	*1.071*	0	138	95.1	limit	1.000	199265	*1.107*	0	171	82.2
	limit	149332	limit	1.000	266935	*1.787*	0	207	86.8	limit	1.000	257096	*1.721*	0	199	70.0
neos-848150	16.2	26	15.0	**0.929**	23	0.976	0	3	226.0	15.4	0.952	27	1.008	0	6	16.0
	15.9	22	15.7	0.987	22	1.000	0	0	0.0	15.8	0.991	22	1.000	0	0	0.0
	1.4	1	1.4	0.996	1	1.000	0	0	0.0	1.4	1.000	1	1.000	0	0	0.0
	17.4	30	17.4	1.001	30	1.000	0	0	0.0	17.4	0.999	30	1.000	0	0	0.0
neos-848198	limit	1522	limit	1.000	1109	**0.745**	0	14	53.6	limit	1.000	1304	**0.866**	2	53	55.0
	limit	1377	limit	1.000	1132	**0.834**	0	14	53.1	limit	1.000	1288	**0.940**	2	58	57.3
	limit	2743	limit	1.000	1923	**0.712**	0	16	71.9	limit	1.000	1400	**0.528**	0	26	57.3
	limit	1290	limit	1.000	2441	*1.828*	0	21	83.5	limit	1.000	1916	*1.450*	2	33	62.0
neos-848589	3390.2	120	3198.0	**0.943**	117	0.986	0	0	31.0	3427.8	1.011	120	1.000	0	0	27.0
	2241.4	45	2470.7	*1.102*	45	1.000	0	0	21.0	2256.3	1.007	45	1.000	0	0	35.0
	1473.2	23	1472.0	0.999	23	1.000	0	0	0.0	1467.7	0.996	23	1.000	0	0	0.0
	1341.7	49	1439.4	*1.073*	49	1.000	0	0	55.0	1341.4	1.000	49	1.000	0	0	0.0
neos-848845	2655.1	136105	1161.7	**0.438**	54283	**0.399**	0	81	141.4	533.4	**0.201**	20967	**0.155**	0	117	167.2
	146.2	1709	648.9	*4.414*	29867	*16.566*	0	443	55.3	633.0	*4.306*	28259	*15.677*	0	174	89.1
	166.1	1614	173.4	1.044	2323	*1.414*	0	73	141.8	605.2	*3.628*	24342	*14.260*	0	110	128.6
	4445.6	244106	224.4	**0.051**	3297	**0.014**	0	91	22.0	966.5	**0.218**	48282	**0.198**	0	267	56.9
neos-849702	179.9	5441	316.7	*1.756*	12631	*2.298*	0	209	95.5	198.5	*1.103*	6913	*1.266*	0	90	43.3
	109.6	2429	130.4	*1.188*	3749	*1.522*	0	160	58.0	191.4	*1.739*	6739	*2.704*	0	275	43.5
	445.8	18527	3214.3	*7.197*	192391	*10.334*	0	289	159.0	728.5	*1.633*	35387	*1.905*	0	243	124.2
	237.4	7748	105.7	**0.447**	1786	**0.240**	0	121	102.0	2227.5	*9.347*	101149	*12.901*	0	1330	51.2
neos-850681	11.7	6	8.7	**0.763**	6	1.000	0	0	0.0	11.5	0.984	6	1.000	0	0	0.0
	8.8	6	8.9	1.008	6	1.000	0	0	0.0	8.8	0.997	6	1.000	0	0	0.0
	7.4	6	7.4	1.004	6	1.000	0	0	0.0	7.5	1.005	6	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: CONFLICT DIVING

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	12.8	7	12.8	0.993	7	1.000	0	0	0.0	13.0	1.011	7	1.000	0	0	0.0
neos-856059	limit	249641	limit	1.000	290602	*1.164*	0	1212	45.5	limit	1.000	311747	*1.249*	0	1014	49.8
	limit	310287	5991.4	**0.832**	259764	**0.837**	0	1919	36.0	3738.5	**0.519**	148544	**0.479**	0	774	50.1
	2337.2	120655	5903.2	*2.525*	250654	*2.077*	0	1461	43.5	6366.6	*2.723*	270323	*2.239*	0	1556	46.7
	5440.9	223611	6813.7	*1.252*	285239	*1.275*	1	624	35.2	2356.7	**0.433**	103861	**0.465**	0	629	44.1
neos-859770	167.8	1	168.0	1.001	1	1.000	0	0	0.0	167.7	0.999	1	1.000	0	0	0.0
	189.8	1	192.2	1.012	1	1.000	0	0	0.0	196.0	1.032	1	1.000	0	0	0.0
	165.0	1	165.2	1.001	1	1.000	0	0	0.0	166.5	1.009	1	1.000	0	0	0.0
	173.9	1	174.0	1.000	1	1.000	0	0	0.0	175.9	1.011	1	1.000	0	0	0.0
neos-860244	6.1	1	6.1	0.999	1	1.000	0	0	0.0	6.2	1.011	1	1.000	0	0	0.0
	6.7	1	6.6	0.993	1	1.000	0	0	0.0	6.6	0.992	1	1.000	0	0	0.0
	6.8	1	6.9	1.001	1	1.000	0	0	0.0	6.8	0.999	1	1.000	0	0	0.0
	5.3	1	5.4	1.016	1	1.000	0	0	0.0	5.3	1.002	1	1.000	0	0	0.0
neos-860300	22.7	2	22.8	1.001	2	1.000	0	0	0.0	22.9	1.007	2	1.000	0	0	0.0
	20.5	2	20.6	1.004	2	1.000	0	0	0.0	20.4	0.997	2	1.000	0	0	0.0
	24.0	3	24.1	1.003	3	1.000	0	0	0.0	24.1	1.003	3	1.000	0	0	0.0
	21.0	2	21.0	1.001	2	1.000	0	0	0.0	21.0	1.000	2	1.000	0	0	0.0
neos-862348	17.8	185	19.0	*1.064*	166	**0.933**	0	0	0.0	17.6	0.990	184	0.996	0	0	0.0
	9.8	38	9.7	0.993	38	1.000	0	0	0.0	9.7	0.993	38	1.000	0	0	0.0
	27.3	710	22.0	**0.814**	209	**0.381**	0	0	0.0	22.1	**0.817**	209	**0.381**	0	0	0.0
	16.5	4	16.6	1.007	4	1.000	0	0	0.0	16.8	1.015	4	1.000	0	0	0.0
neos-863472	76.3	49643	62.5	**0.822**	42426	**0.855**	0	289	27.0	69.8	**0.916**	46547	**0.938**	0	499	26.8
	66.3	43405	68.2	1.029	48044	*1.107*	0	421	29.1	54.9	**0.830**	37887	**0.873**	0	485	26.6
	44.1	28602	48.2	*1.093*	30659	*1.072*	0	213	31.4	43.8	0.993	27863	0.974	0	353	28.2
	61.8	41542	61.7	0.997	44326	*1.067*	0	292	30.6	54.9	**0.889**	38730	**0.932**	0	372	28.9
neos-872648	limit	10	limit	1.000	9	0.991	0	0	0.0	limit	1.000	10	1.000	0	0	0.0
	limit	222	limit	1.000	213	0.972	0	2	275.3	limit	1.000	210	0.963	0	2	275.3
	limit	30	limit	1.000	29	0.992	0	0	0.0	limit	1.000	30	1.000	0	0	0.0
	limit	219	limit	1.000	204	0.953	0	0	246.5	limit	1.000	204	0.953	0	0	246.5
neos-873061	limit	6397	limit	1.000	1511	**0.248**	0	2	350.4	limit	1.000	992	**0.168**	0	0	360.0
	limit	10067	limit	1.000	7959	**0.793**	0	4	309.3	limit	1.000	9194	**0.914**	0	2	319.8
	limit	996	limit	1.000	1414	*1.381*	0	2	265.2	limit	1.000	1003	1.006	0	0	318.4
	limit	7157	limit	1.000	7853	*1.096*	0	0	319.2	limit	1.000	4949	**0.696**	0	0	314.0
neos-876808	limit	19	limit	1.000	20	1.008	0	0	0.0	limit	1.000	19	1.000	0	0	0.0
	limit	13	limit	1.000	13	1.000	0	0	0.0	limit	1.000	13	1.000	0	0	0.0
	limit	2	limit	1.000	2	1.000	0	0	0.0	limit	1.000	2	1.000	0	0	0.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	1	limit	1.000	1	1.000	0	0	0.0	limit	1.000	1	1.000	0	0	0.0
neos-880324	1.1	12	1.1	0.953	12	1.000	0	0	0.0	1.1	0.967	12	1.000	0	0	0.0
	1.4	8	1.4	1.004	8	1.000	0	0	0.0	1.4	1.000	8	1.000	0	0	0.0
	1.0	4	0.9	0.961	4	1.000	0	0	0.0	1.0	1.000	4	1.000	0	0	0.0
	1.3	19	1.3	0.979	19	1.000	0	0	0.0	1.3	0.983	19	1.000	0	0	0.0
neos-881765	4.3	54	4.3	0.993	54	1.000	0	0	0.0	4.4	1.007	54	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	2.9	22	3.0	1.010	22	1.000	0	0	0.0	3.0	1.013	22	1.000	0	0	0.0
	3.1	23	3.1	1.010	23	1.000	0	0	0.0	3.1	1.010	23	1.000	0	0	0.0
neos-885086	6516.2	530	1800.0	**0.276**	236	**0.533**	0	0	458.0	limit	*1.105*	872	*1.543*	0	1	213.0
	4611.0	201	limit	*1.561*	837	*3.113*	0	0	353.0	4601.3	0.998	201	1.000	0	0	0.0
	2076.7	82	limit	*3.466*	659	*4.170*	0	0	383.0	2073.7	0.999	82	1.000	0	0	0.0
	2004.7	78	3713.7	*1.852*	272	*2.090*	0	0	372.0	3740.5	*1.865*	201	*1.691*	0	0	0.0
neos-885524	limit	1352	77.8	**0.011**	401	**0.345**	0	0	595.0	470.6	**0.065**	615	**0.492**	0	3	38.5
	25.7	25	25.1	0.976	25	1.000	0	0	0.0	25.1	0.978	25	1.000	0	0	0.0
	limit	3709	limit	1.000	4998	*1.338*	0	0	828.0	limit	1.000	4075	*1.096*	0	11	72.6
	limit	3152	limit	1.000	4396	*1.383*	0	6	323.7	5691.0	**0.790**	3237	1.026	0	2	67.2
neos-886822	4163.4	442088	3310.3	**0.795**	211217	**0.478**	0	455	77.4	3417.5	**0.821**	281362	**0.637**	0	393	88.5
	3276.4	320443	2028.5	**0.619**	150024	**0.468**	0	142	79.1	2557.0	**0.780**	215630	**0.673**	0	223	100.2
	2347.8	168397	3381.1	*1.440*	197060	*1.170*	0	540	69.4	4144.7	*1.765*	319303	*1.896*	0	321	90.1
	4379.5	523770	3085.8	**0.705**	235585	**0.450**	0	116	78.4	1805.5	**0.412**	160715	**0.307**	0	275	78.8
neos-892255	96.6	823	92.9	0.962	751	**0.922**	0	2	73.0	85.8	**0.889**	696	**0.862**	0	4	95.0
	107.7	477	117.0	*1.086*	487	1.017	0	5	18.0	86.7	**0.807**	408	**0.880**	0	0	45.0
	102.3	313	98.4	0.962	298	0.964	0	9	30.0	69.9	**0.686**	292	**0.949**	0	4	49.0
	52.5	290	52.6	1.002	290	1.000	0	0	0.0	52.7	1.004	290	1.000	0	0	0.0
neos-905856	382.4	28341	24.8	**0.067**	375	**0.017**	0	43	56.0	103.3	**0.272**	3718	**0.134**	0	110	27.6
	271.0	23676	125.8	**0.466**	7861	**0.335**	0	360	45.7	253.8	**0.937**	29537	*1.247*	0	249	37.9
	380.1	35578	167.4	**0.442**	9876	**0.280**	0	217	59.4	257.7	**0.679**	17384	**0.490**	0	516	34.3
	278.0	16427	754.5	*2.708*	52807	*3.201*	0	543	51.9	1037.1	*3.720*	83690	*5.070*	0	944	31.6
neos-906865	158.2	22295	135.9	**0.860**	17218	**0.773**	0	47	45.8	87.0	**0.553**	12330	**0.555**	0	53	50.8
	222.0	35672	174.6	**0.787**	24206	**0.679**	0	18	44.9	174.0	**0.785**	24329	**0.683**	0	198	41.5
	177.3	22778	177.0	0.998	27518	*1.207*	0	14	41.9	168.2	**0.949**	23344	1.025	0	124	46.5
	98.5	16324	142.5	*1.442*	22634	*1.384*	0	31	52.2	72.5	**0.738**	10074	**0.619**	0	134	39.4
neos-911880	1543.2	729520	419.1	**0.272**	166853	**0.229**	0	44	83.1	544.9	**0.354**	263970	**0.362**	0	12	64.2
	limit	4609415	limit	1.000	4427319	0.960	0	291	80.4	limit	1.000	5596963	*1.214*	0	254	78.3
	limit	5990982	limit	1.000	1649172	**0.275**	0	77	76.1	limit	1.000	3803581	**0.635**	0	127	84.4

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	4309531	limit	1.000	5869887	*1.362*	0	214	80.0	limit	1.000	3712764	**0.862**	0	200	63.9
neos-911970	161.1	95396	limit	*44.437*	5090332	*53.305*	0	276	94.6	199.9	*1.240*	82333	**0.863**	0	9	60.0
	limit	3329130	limit	1.000	5084186	*1.527*	0	582	82.0	limit	1.000	5349928	*1.607*	0	1061	88.0
	limit	7208332	limit	1.000	4048264	**0.562**	0	109	84.8	limit	1.000	3777856	**0.524**	0	80	68.3
	limit	6609750	366.5	**0.051**	111525	**0.017**	0	14	93.5	limit	1.000	6038030	**0.914**	0	371	91.7
neos-912015	9.9	28	10.0	1.001	28	1.000	0	0	0.0	10.0	1.005	28	1.000	0	0	0.0
	6.1	21	6.0	0.987	21	1.000	0	0	0.0	6.2	1.008	21	1.000	0	0	0.0
	17.6	845	18.4	1.040	567	**0.706**	0	19	40.0	18.9	*1.072*	943	*1.104*	0	22	20.0
	9.5	29	9.6	1.009	29	1.000	0	0	0.0	9.6	1.007	29	1.000	0	0	0.0
neos-912023	11.0	20	11.0	1.004	20	1.000	0	0	0.0	10.7	0.980	20	1.000	0	0	0.0
	6.2	5	6.3	1.024	5	1.000	0	0	0.0	6.3	1.024	5	1.000	0	0	0.0
	8.3	22	8.4	1.005	22	1.000	0	0	0.0	8.3	0.997	22	1.000	0	0	0.0
	11.9	99	11.8	0.998	99	1.000	0	0	0.0	11.8	0.995	99	1.000	0	0	0.0
neos-913984	2.8	1	2.7	0.979	1	1.000	0	0	0.0	2.8	1.005	1	1.000	0	0	0.0
	2.7	1	2.7	1.003	1	1.000	0	0	0.0	2.7	1.005	1	1.000	0	0	0.0
	2.7	1	2.7	1.014	1	1.000	0	0	0.0	2.8	1.025	1	1.000	0	0	0.0
	2.7	1	2.7	1.000	1	1.000	0	0	0.0	2.7	1.000	1	1.000	0	0	0.0
neos-914441	8.8	1	8.9	1.005	1	1.000	0	0	0.0	8.9	1.005	1	1.000	0	0	0.0
	4.6	1	4.6	0.989	1	1.000	0	0	0.0	4.6	0.995	1	1.000	0	0	0.0
	17.2	2	17.1	0.997	2	1.000	0	0	0.0	17.1	0.995	2	1.000	0	0	0.0
	10.4	2	10.4	1.004	2	1.000	0	0	0.0	10.5	1.011	2	1.000	0	0	0.0
neos-916173	115.8	10892	105.9	**0.916**	10649	0.978	0	12	58.2	119.7	1.033	11472	*1.053*	0	54	59.4
	149.6	14771	88.2	**0.593**	7774	**0.529**	0	4	59.7	139.9	**0.936**	13490	**0.914**	0	26	56.8
	181.3	19965	154.8	**0.855**	12392	**0.623**	0	11	57.2	205.0	*1.130*	24962	*1.249*	0	35	54.8
	122.7	13274	104.7	**0.854**	8603	**0.651**	0	25	57.7	108.5	**0.885**	10810	**0.816**	0	13	60.9
neos-916792	1020.9	103012	1368.2	*1.340*	138606	*1.345*	0	84	71.2	1374.5	*1.346*	161197	*1.564*	0	24	73.9
	1101.8	124932	1431.2	*1.299*	161126	*1.289*	1	394	69.9	957.5	**0.869**	99827	**0.799**	0	257	67.2
	2288.4	236234	965.7	**0.422**	87110	**0.369**	0	53	65.4	761.6	**0.333**	67235	**0.285**	0	92	66.1
	850.2	70920	1863.8	*2.191*	230216	*3.243*	0	78	68.8	2148.7	*2.526*	213105	*3.002*	0	253	70.1
neos-930752	limit	2977	limit	1.000	2309	**0.783**	0	0	95.3	limit	1.000	2102	**0.716**	0	150	87.1
	limit	2298	limit	1.000	2382	1.035	0	0	99.0	limit	1.000	2122	**0.927**	0	123	88.4
	limit	1557	limit	1.000	2423	*1.523*	0	41	109.9	limit	1.000	3746	*2.321*	0	43	128.9
	limit	2497	limit	1.000	2478	0.993	0	44	114.3	limit	1.000	2530	1.013	0	106	100.0
neos-931517	limit	1984	limit	1.000	1484	**0.760**	0	0	835.1	limit	1.000	1476	**0.756**	0	0	100.7
	limit	1298	limit	1.000	1609	*1.222*	0	0	850.7	limit	1.000	1248	0.964	0	0	226.4
	limit	903	limit	1.000	1070	*1.167*	0	0	850.7	limit	1.000	833	**0.930**	0	0	142.8

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	1211	limit	1.000	1283	*1.055*	0	0	852.0	limit	1.000	1188	0.982	0	0	190.7
neos-931538	90.2	5	75.7	**0.841**	5	1.000	0	0	0.0	72.1	**0.801**	5	1.000	0	0	0.0
	93.3	5	93.7	1.004	5	1.000	0	0	0.0	93.9	1.006	5	1.000	0	0	0.0
	115.9	5	102.1	**0.882**	5	1.000	0	0	0.0	115.6	0.997	5	1.000	0	0	0.0
	115.1	5	100.7	**0.876**	5	1.000	0	0	0.0	96.5	**0.840**	5	1.000	0	0	0.0
neos-932721	3.7	1	3.7	1.002	1	1.000	0	0	0.0	3.7	1.006	1	1.000	0	0	0.0
	3.0	1	2.9	0.970	1	1.000	0	0	0.0	3.0	1.007	1	1.000	0	0	0.0
	2.9	1	2.9	0.990	1	1.000	0	0	0.0	2.9	0.985	1	1.000	0	0	0.0
	2.6	1	2.5	0.986	1	1.000	0	0	0.0	2.5	0.989	1	1.000	0	0	0.0
neos-932816	limit	2390	limit	1.000	1101	**0.482**	0	3	628.5	limit	1.000	1072	**0.471**	0	0	654.1
	2672.5	414	3130.2	*1.171*	582	*1.327*	0	18	701.4	3078.3	*1.152*	594	*1.350*	0	15	699.1
	1375.8	201	1326.2	0.964	191	0.967	0	0	847.0	1372.4	0.998	201	1.000	0	0	0.0
	3406.9	577	2808.0	**0.824**	566	0.984	0	6	780.2	3186.0	**0.935**	534	**0.936**	0	27	357.4
neos-933364	38.5	7312	34.1	**0.888**	4170	**0.576**	0	3	45.4	32.6	**0.851**	2151	**0.304**	0	0	37.7
	39.1	5010	65.8	*1.667*	20459	*4.023*	0	2	52.0	43.3	*1.106*	4598	**0.919**	0	0	47.2
	36.4	9857	34.4	**0.948**	5057	**0.518**	0	0	40.6	40.5	*1.109*	10120	1.026	0	4	42.2
	64.2	11640	119.1	*1.844*	32533	*2.780*	0	7	61.6	72.1	*1.121*	16270	*1.394*	0	8	53.2
neos-933550	4.8	27	4.7	0.979	27	1.000	0	0	0.0	4.7	0.990	27	1.000	0	0	0.0
	4.8	28	4.7	0.988	28	1.000	0	0	0.0	4.6	0.981	28	1.000	0	0	0.0
	4.7	31	4.8	1.007	31	1.000	0	0	0.0	4.8	1.009	31	1.000	0	0	0.0
	4.3	25	4.2	0.994	25	1.000	0	0	0.0	4.3	1.000	25	1.000	0	0	0.0
neos-933562	limit	37510	limit	1.000	34409	**0.918**	0	89	237.5	limit	1.000	41331	*1.102*	0	2995	65.3
	limit	33828	limit	1.000	63570	*1.877*	0	88	233.4	limit	1.000	45204	*1.335*	0	283	129.1
	limit	21832	limit	1.000	22068	1.011	0	45	228.3	limit	1.000	21847	1.001	0	448	82.6
	limit	56026	limit	1.000	39648	**0.708**	0	62	228.7	limit	1.000	70192	*1.252*	0	156	88.5
neos-933638	4352.1	737	limit	*1.654*	887	*1.179*	0	4	855.5	1456.6	**0.335**	178	**0.332**	0	0	0.0
	limit	949	2894.7	**0.402**	246	**0.330**	0	0	936.0	5504.6	**0.765**	485	**0.558**	0	0	1132.5
	3010.8	477	5837.4	*1.939*	907	*1.745*	0	4	676.5	limit	*2.391*	629	*1.263*	0	39	400.5
	limit	427	4284.9	**0.595**	767	*1.645*	0	10	912.5	4837.9	**0.672**	526	*1.188*	0	88	84.3
neos-933815	23.9	2843	34.6	*1.428*	12053	*4.129*	0	45	36.8	89.0	*3.606*	60746	*20.675*	0	55	40.5
	31.6	13520	44.7	*1.400*	23405	*1.726*	0	11	42.4	78.6	*2.438*	56757	*4.175*	0	64	40.7
	222.3	74601	40.2	**0.185**	15872	**0.214**	0	16	46.3	50.0	**0.228**	17179	**0.231**	0	14	48.2
	23.7	4924	36.4	*1.515*	15493	*3.104*	0	40	48.1	37.4	*1.557*	20155	*4.032*	0	17	39.1
neos-933966	1498.2	366	limit	*4.803*	2065	*4.646*	0	41	804.4	3389.0	*2.261*	1422	*3.266*	0	70	525.8
	4877.1	1243	1793.5	**0.368**	114	**0.159**	0	2	878.5	1980.2	**0.406**	231	**0.246**	0	0	1242.0
	1450.1	385	5337.8	*3.679*	1618	*3.542*	0	4	708.7	5495.6	*3.788*	993	*2.254*	0	167	593.8

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving							
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	1965.8	121	2847.3	*1.448*	1091	*5.389*	0	0	666.5	1203.5	**0.612**	58	**0.715**	0	0	0.0
neos-934278	limit	1892	limit	1.000	715	**0.409**	0	0	834.4	limit	1.000	519	**0.311**	0	0	676.0
	limit	1155	limit	1.000	1827	*1.535*	0	12	710.0	limit	1.000	3141	*2.582*	0	356	255.9
	limit	1745	limit	1.000	462	**0.305**	0	0	825.2	limit	1.000	890	**0.537**	0	68	100.8
	limit	802	7122.1	0.989	2652	*3.051*	0	226	475.1	limit	1.000	1545	*1.824*	0	64	363.9
neos-934441	limit	595	limit	1.000	597	1.003	0	0	857.7	limit	1.000	740	*1.209*	0	16	80.0
	limit	1585	limit	1.000	1757	*1.102*	0	28	588.4	limit	1.000	1671	*1.051*	0	42	483.5
	limit	486	limit	1.000	533	*1.080*	0	0	840.0	limit	1.000	653	*1.285*	0	0	69.0
	limit	1803	limit	1.000	774	**0.459**	0	20	644.0	limit	1.000	700	**0.420**	0	0	466.0
neos-934531	95.5	1	95.3	0.999	1	1.000	0	0	0.0	97.4	1.020	1	1.000	0	0	0.0
	138.6	2	138.5	0.999	2	1.000	0	0	0.0	138.4	0.999	2	1.000	0	0	0.0
	173.1	12	173.2	1.000	12	1.000	0	0	0.0	174.3	1.007	12	1.000	0	0	0.0
	133.8	10	134.3	1.004	10	1.000	0	0	0.0	133.1	0.995	10	1.000	0	0	0.0
neos-935234	limit	485	limit	1.000	1093	*2.039*	0	48	716.9	limit	1.000	672	*1.320*	0	7	419.1
	limit	773	limit	1.000	445	**0.624**	0	0	826.7	limit	1.000	441	**0.620**	0	12	108.7
	limit	606	limit	1.000	721	*1.163*	0	0	1049.0	limit	1.000	583	0.967	0	14	390.0
	limit	505	limit	1.000	984	*1.792*	0	0	896.4	limit	1.000	485	0.967	0	24	120.8
neos-935348	limit	678	limit	1.000	441	**0.695**	0	1	845.6	limit	1.000	422	**0.671**	0	1	84.2
	limit	551	limit	1.000	506	**0.931**	0	1	693.2	limit	1.000	328	**0.657**	0	22	50.7
	limit	497	limit	1.000	458	**0.935**	0	0	801.7	limit	1.000	532	*1.059*	0	1	286.5
	limit	489	limit	1.000	461	0.952	0	0	823.3	limit	1.000	1106	*2.048*	0	0	355.0
neos-935496	limit	1191133	limit	1.000	1255774	*1.054*	0	629	103.3	limit	1.000	1080735	**0.907**	0	147	121.8
	limit	788283	limit	1.000	846160	*1.073*	0	219	153.8	limit	1.000	873923	*1.109*	0	459	105.1
	limit	733418	limit	1.000	799364	*1.090*	0	210	119.8	limit	1.000	806205	*1.099*	0	208	112.5
	limit	971382	limit	1.000	1252686	*1.290*	0	241	122.8	limit	1.000	867303	**0.893**	0	378	101.0
neos-935627	limit	516	limit	1.000	522	1.010	0	0	836.0	limit	1.000	471	**0.927**	0	6	254.7
	limit	2367	limit	1.000	541	**0.260**	0	0	968.2	limit	1.000	454	**0.225**	0	3	73.8
	limit	513	limit	1.000	660	*1.240*	0	0	813.7	limit	1.000	520	1.011	0	1	263.8
	limit	464	limit	1.000	601	*1.243*	0	0	835.0	limit	1.000	530	*1.117*	0	0	290.5
neos-935674	limit	534034	limit	1.000	616393	*1.154*	0	2041	93.6	limit	1.000	701621	*1.314*	0	1430	105.2
	limit	867257	limit	1.000	876808	1.011	0	366	140.0	limit	1.000	980052	*1.130*	0	1164	111.3
	limit	743414	limit	1.000	849350	*1.142*	0	478	164.8	limit	1.000	647251	**0.871**	0	1219	98.0
	limit	1086771	limit	1.000	1184963	*1.090*	0	6481	81.2	limit	1.000	865566	**0.796**	0	2097	82.7
neos-935769	limit	2983	limit	1.000	934	**0.335**	0	21	668.4	limit	1.000	773	**0.283**	0	5	270.4
	limit	1066	6361.8	**0.884**	4126	*3.624*	0	56	303.5	2635.1	**0.366**	331	**0.370**	0	2	98.7
	limit	2240	limit	1.000	677	**0.332**	0	18	546.2	2426.6	**0.337**	305	**0.173**	0	8	72.5

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	6573.5	2397	3427.1	**0.521**	417	**0.207**	0	1	551.0	limit	*1.095*	1049	**0.460**	0	6	90.0
neos-936660	limit	615	limit	1.000	724	*1.152*	0	1	784.5	limit	1.000	795	*1.252*	0	5	346.8
	limit	1419	limit	1.000	410	**0.336**	0	1	845.3	limit	1.000	529	**0.414**	0	4	118.0
	7050.4	1769	limit	1.021	1127	**0.657**	0	0	427.3	limit	1.021	1072	**0.627**	0	97	425.2
	limit	462	limit	1.000	1261	*2.422*	0	0	383.0	limit	1.000	1018	*1.989*	0	84	98.2
neos-937446	3015.9	771	1355.6	**0.450**	263	**0.417**	0	0	209.0	limit	*2.387*	1996	*2.406*	0	224	165.8
	limit	1682	limit	1.000	1309	**0.791**	0	0	146.8	5265.7	**0.731**	534	**0.356**	0	2	109.5
	limit	955	limit	1.000	1248	*1.278*	0	35	372.5	4558.4	**0.633**	1436	*1.456*	0	3	172.4
	limit	1482	limit	1.000	1731	*1.157*	0	98	282.4	2927.3	**0.407**	413	**0.324**	0	0	1278.0
neos-937511	limit	663	5476.3	**0.761**	1866	*2.577*	0	54	300.0	4956.1	**0.688**	1095	*1.566*	0	1	610.3
	limit	761	3879.0	**0.539**	896	*1.157*	0	72	731.5	2824.6	**0.392**	206	**0.355**	0	2	58.5
	6362.0	687	limit	*1.132*	1162	*1.604*	0	91	539.3	4721.1	**0.742**	1121	*1.551*	0	67	192.8
	4683.4	1441	6594.8	*1.408*	2031	*1.383*	0	116	368.6	1469.5	**0.314**	163	**0.171**	0	0	149.0
neos-937815	limit	663	limit	1.000	789	*1.165*	0	0	969.6	limit	1.000	2328	*3.182*	0	45	465.2
	limit	771	limit	1.000	717	**0.938**	0	1	976.9	limit	1.000	1689	*2.054*	0	2	365.8
	limit	657	limit	1.000	661	1.005	0	0	977.2	limit	1.000	1110	*1.598*	0	9	394.3
	limit	1242	limit	1.000	1793	*1.411*	0	1	858.7	limit	1.000	734	**0.621**	0	12	136.2
neos-941262	limit	792	limit	1.000	608	**0.794**	0	0	786.2	limit	1.000	1315	*1.586*	0	64	191.7
	limit	743	limit	1.000	723	0.976	0	1	621.4	limit	1.000	527	**0.744**	0	67	513.1
	limit	711	limit	1.000	841	*1.160*	0	0	1033.0	limit	1.000	738	1.033	0	3	500.6
	limit	807	limit	1.000	722	**0.906**	0	0	762.2	limit	1.000	659	**0.837**	0	36	260.5
neos-941313	limit	171	limit	1.000	178	1.026	0	11	505.3	4273.7	**0.594**	56	**0.576**	0	9	121.0
	1369.2	5	1390.2	1.015	5	1.000	0	0	0.0	1370.6	1.001	5	1.000	0	0	0.0
	1523.3	5	835.0	**0.548**	6	1.010	0	0	0.0	4772.2	*3.131*	350	*4.286*	0	2	58.0
	5887.8	201	5719.1	0.971	185	**0.947**	0	0	489.0	6868.4	*1.167*	274	*1.243*	0	18	216.0
neos-941698	26.7	953	23.4	**0.883**	483	**0.554**	0	19	25.5	26.2	0.984	836	**0.889**	0	49	30.5
	11.2	71	11.1	0.998	71	1.000	0	0	0.0	11.2	0.999	71	1.000	0	0	0.0
	16.9	123	16.7	0.991	123	1.000	0	0	0.0	16.7	0.990	123	1.000	0	0	0.0
	14.8	99	14.7	0.997	99	1.000	0	0	0.0	14.7	0.999	99	1.000	0	0	0.0
neos-941717	limit	788323	limit	1.000	940263	*1.193*	0	251	167.6	limit	1.000	871332	*1.105*	0	696	115.8
	limit	679140	limit	1.000	631355	**0.930**	0	157	189.9	limit	1.000	772858	*1.138*	0	130	184.1
	limit	983858	limit	1.000	1101893	*1.120*	0	99	174.3	limit	1.000	1052585	*1.070*	0	668	86.5
	limit	737191	limit	1.000	807380	*1.095*	0	246	138.4	limit	1.000	959423	*1.301*	0	2016	79.5
neos-941782	limit	1376577	limit	1.000	1328870	0.965	0	1912	116.1	limit	1.000	1282289	**0.932**	0	2918	91.0
	limit	1328103	limit	1.000	1087049	**0.819**	0	397	132.9	limit	1.000	929692	**0.700**	0	637	90.3
	limit	940019	limit	1.000	1339107	*1.425*	0	606	146.3	limit	1.000	1139969	*1.213*	0	1182	86.4

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	1266159	limit	1.000	1366871	*1.080*	0	2941	100.1	limit	1.000	1495457	*1.181*	0	9847	65.7
neos-942323	4.8	30	4.8	1.002	30	1.000	0	0	0.0	4.6	0.967	30	1.000	0	0	0.0
	8.9	490	8.8	0.980	490	1.000	0	0	0.0	8.8	0.989	490	1.000	0	0	0.0
	5.9	97	5.8	0.997	97	1.000	0	0	0.0	5.8	0.997	97	1.000	0	0	0.0
	9.3	714	9.2	0.988	714	1.000	0	0	0.0	9.3	0.997	714	1.000	0	0	0.0
neos-942830	1711.8	470887	1442.4	**0.843**	384859	**0.817**	0	1416	75.4	998.8	**0.584**	240739	**0.511**	0	1236	44.3
	1148.5	345134	824.3	**0.718**	243577	**0.706**	0	1459	79.1	2329.1	*2.027*	669215	*1.939*	0	4134	53.0
	514.8	95831	687.8	*1.335*	182134	*1.900*	0	485	74.1	1360.2	*2.639*	420629	*4.386*	0	1661	44.4
	2406.5	621947	1458.3	**0.606**	308675	**0.496**	0	659	100.0	2724.8	*1.132*	823956	*1.325*	0	1897	52.6
neos-942886	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.6	1.047	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
neos-948126	limit	753	limit	1.000	653	**0.883**	0	0	669.5	limit	1.000	672	**0.905**	0	14	57.8
	limit	960	limit	1.000	1579	*1.584*	0	0	832.0	limit	1.000	775	**0.825**	0	7	656.0
	limit	637	limit	1.000	717	*1.109*	0	0	659.2	limit	1.000	897	*1.353*	0	0	727.6
	limit	904	limit	1.000	1001	*1.097*	0	0	806.7	limit	1.000	692	**0.789**	0	6	577.5
neos-948268	11.7	1	11.4	0.980	1	1.000	0	0	0.0	11.8	1.011	1	1.000	0	0	0.0
	15.2	1	15.3	1.003	1	1.000	0	0	0.0	15.2	0.998	1	1.000	0	0	0.0
	10.1	1	10.0	0.994	1	1.000	0	0	0.0	10.0	0.996	1	1.000	0	0	0.0
	13.4	1	13.4	0.997	1	1.000	0	0	0.0	13.3	0.997	1	1.000	0	0	0.0
neos-948346	limit	80	limit	1.000	81	1.006	0	0	318.0	limit	1.000	81	1.006	0	6	48.0
	limit	142	limit	1.000	250	*1.446*	0	46	84.7	limit	1.000	82	**0.752**	0	0	47.0
	limit	104	limit	1.000	264	*1.784*	2	9	261.3	limit	1.000	155	*1.250*	0	175	298.0
	limit	152	limit	1.000	110	**0.833**	0	0	117.0	limit	1.000	113	**0.845**	0	12	28.0
neos-950242	635.2	156	430.0	**0.678**	137	**0.926**	0	0	349.3	420.7	**0.663**	78	**0.695**	0	41	145.7
	247.7	49	292.9	*1.182*	62	*1.087*	0	0	367.0	268.9	*1.085*	58	*1.060*	0	30	78.0
	309.8	103	263.6	**0.851**	39	**0.685**	0	0	560.0	311.0	1.004	70	**0.837**	0	31	124.0
	385.3	59	741.4	*1.922*	194	*1.849*	0	0	220.0	560.8	*1.454*	114	*1.346*	0	118	67.0
neos-952987	limit	13	limit	1.000	13	1.000	0	0	2685.0	limit	1.000	12	0.991	0	0	0.0
	limit	19	limit	1.000	19	1.000	0	0	2591.0	limit	1.000	19	1.000	0	0	0.0
	limit	7	limit	1.000	7	1.000	0	0	0.0	limit	1.000	8	1.009	0	0	0.0
	limit	28	limit	1.000	27	0.992	0	0	2473.0	limit	1.000	27	0.992	0	0	0.0
neos-953928	489.7	73	516.2	*1.054*	97	*1.139*	0	0	128.0	555.8	*1.135*	89	*1.092*	0	0	101.0
	460.4	70	452.9	0.984	72	1.012	0	0	126.0	432.6	**0.940**	53	**0.900**	0	48	76.0
	673.5	49	662.8	0.984	43	0.960	1	0	28.0	551.7	**0.819**	27	**0.852**	0	0	36.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	442.3	34	855.9	*1.933*	69	*1.261*	0	0	174.3	548.1	*1.239*	46	*1.090*	0	0	86.0
neos-954925	5325.6	119	6805.4	*1.278*	326	*1.945*	0	0	125.2	2207.4	**0.415**	92	**0.877**	0	0	291.0
	2744.2	81	3209.6	*1.170*	93	*1.066*	0	0	39.0	2872.2	1.047	155	*1.409*	0	0	324.0
	4097.1	252	3631.8	**0.886**	160	**0.739**	0	0	182.3	4117.2	1.005	191	**0.827**	0	3	104.0
	3339.2	78	2834.6	**0.849**	41	**0.792**	0	0	0.0	4337.6	*1.299*	882	*5.517*	0	0	149.0
neos-955215	42.5	61981	18.9	**0.458**	17654	**0.286**	0	62	25.4	21.1	**0.507**	21699	**0.351**	0	100	24.6
	22.1	20031	16.2	**0.743**	7955	**0.400**	0	77	23.3	12.6	**0.589**	9325	**0.468**	0	45	25.5
	16.9	12998	16.0	0.951	17102	*1.313*	0	84	24.3	14.0	**0.840**	10838	**0.835**	0	60	24.4
	12.0	7728	8.9	**0.761**	3797	**0.498**	0	26	20.8	10.4	**0.880**	5507	**0.716**	0	34	24.0
neos-955800	93.1	2717	74.1	**0.798**	2143	**0.796**	0	111	66.4	70.0	**0.754**	2098	**0.780**	0	50	36.7
	42.9	851	47.9	*1.115*	998	*1.155*	0	54	59.6	50.4	*1.172*	1054	*1.213*	1	160	28.5
	50.1	854	39.5	**0.793**	707	**0.846**	0	0	65.0	55.5	*1.106*	1181	*1.343*	0	86	22.2
	78.6	2357	60.3	**0.771**	1323	**0.579**	0	94	77.4	64.3	**0.820**	1467	**0.638**	0	106	37.5
neos-956971	4945.3	1140	3847.5	**0.778**	284	**0.310**	0	0	62.8	2208.6	**0.447**	107	**0.167**	0	0	424.0
	limit	1472	limit	1.000	219	**0.203**	0	0	32.0	limit	1.000	385	**0.309**	0	46	98.2
	2337.2	72	3483.1	*1.490*	694	*4.616*	0	0	98.5	2380.5	1.019	67	0.971	0	0	102.0
	limit	821	limit	1.000	372	**0.512**	0	15	58.2	limit	1.000	1182	*1.392*	1	132	187.7
neos-957143	4960.7	1625	1233.4	**0.249**	41	**0.082**	0	0	32.0	1343.2	**0.271**	74	**0.101**	0	70	117.5
	53.2	1	4919.6	*90.854*	318	*4.139*	0	0	62.0	52.0	0.979	1	1.000	0	0	0.0
	2918.2	112	5666.3	*1.941*	226	*1.538*	0	28	100.0	3158.4	*1.082*	289	*1.835*	0	5	190.5
	2824.8	130	4441.3	*1.572*	319	*1.822*	0	33	58.5	2797.3	0.990	201	*1.309*	0	36	39.8
neos-957270	2.6	1	2.4	0.966	1	1.000	0	0	0.0	2.5	0.978	1	1.000	0	0	0.0
	2.4	1	2.5	1.015	1	1.000	0	0	0.0	2.4	0.997	1	1.000	0	0	0.0
	2.4	1	2.4	0.994	1	1.000	0	0	0.0	2.4	0.994	1	1.000	0	0	0.0
	2.4	1	2.4	1.003	1	1.000	0	0	0.0	2.4	1.000	1	1.000	0	0	0.0
neos-957323	123.8	2	123.8	1.001	2	1.000	0	0	0.0	77.6	**0.630**	2	1.000	0	0	0.0
	322.2	17	356.1	*1.105*	18	1.009	0	0	0.0	354.6	*1.100*	18	1.009	0	0	0.0
	136.2	3	136.2	1.000	3	1.000	0	0	0.0	137.0	1.006	3	1.000	0	0	0.0
	96.3	2	100.6	1.044	2	1.000	0	0	0.0	96.3	1.000	2	1.000	0	0	0.0
neos-957389	17.4	1	17.6	1.011	1	1.000	0	0	0.0	17.3	0.997	1	1.000	0	0	0.0
	17.4	1	17.5	1.005	1	1.000	0	0	0.0	17.5	1.005	1	1.000	0	0	0.0
	17.4	1	17.4	1.000	1	1.000	0	0	0.0	17.3	0.998	1	1.000	0	0	0.0
	17.4	1	17.4	1.002	1	1.000	0	0	0.0	17.8	1.021	1	1.000	0	0	0.0
neos-960392	849.9	15	849.6	1.000	15	1.000	0	0	0.0	851.7	1.002	15	1.000	0	0	0.0
	1671.7	98	1009.2	**0.604**	28	**0.646**	0	0	86.0	1040.6	**0.623**	34	**0.677**	0	1	56.0
	1067.4	69	2211.1	*2.070*	269	*2.183*	0	1	198.0	1603.8	*1.502*	156	*1.515*	0	1	57.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	1244.5	38	1346.2	*1.082*	58	*1.145*	0	0	170.0	2098.0	*1.685*	298	*2.884*	0	217	104.7
neos-983171	limit	573	limit	1.000	451	**0.819**	0	0	733.8	limit	1.000	389	**0.727**	0	0	1088.7
	limit	618	limit	1.000	556	**0.914**	0	0	856.9	limit	1.000	454	**0.772**	0	0	1086.0
	limit	853	limit	1.000	608	**0.743**	0	0	741.6	limit	1.000	499	**0.629**	0	0	1095.0
	limit	455	limit	1.000	326	**0.768**	0	0	737.0	limit	1.000	404	**0.908**	0	0	998.6
neos-984165	limit	1405	limit	1.000	611	**0.472**	0	0	733.7	limit	1.000	636	**0.489**	0	0	1064.5
	limit	561	limit	1.000	482	**0.880**	0	0	726.1	limit	1.000	518	**0.935**	0	0	937.9
	limit	512	limit	1.000	586	*1.121*	0	0	725.8	limit	1.000	554	*1.069*	0	1	826.5
	limit	823	limit	1.000	516	**0.667**	0	0	723.8	limit	1.000	639	**0.801**	0	5	847.2
neos13	251.9	10896	504.0	*1.997*	23323	*2.130*	0	118	99.8	158.2	**0.629**	5088	**0.472**	0	4	38.0
	144.5	4884	785.3	*5.403*	39311	*7.908*	0	118	98.9	116.7	**0.809**	2858	**0.593**	0	2	52.0
	560.5	27179	101.5	**0.182**	1594	**0.062**	1	0	18.0	977.9	*1.743*	55783	*2.049*	2	109	92.2
	659.1	33273	560.5	**0.851**	23947	**0.721**	0	40	119.0	498.3	**0.756**	28274	**0.850**	0	109	103.2
neos18	28.4	1195	30.1	*1.060*	1291	*1.074*	0	50	19.3	28.4	1.000	1193	0.998	0	44	24.0
	41.4	2800	31.0	**0.755**	1573	**0.577**	0	76	21.4	30.6	**0.747**	1512	**0.556**	0	83	17.4
	29.9	1130	28.0	**0.939**	1011	**0.903**	0	25	40.0	26.8	**0.899**	857	**0.778**	1	61	50.0
	26.5	941	26.3	0.993	946	1.005	0	9	27.0	25.8	0.976	928	0.988	0	9	10.0
net12	831.6	1539	1036.3	*1.246*	2252	*1.435*	0	117	55.3	965.4	*1.161*	1925	*1.236*	1	371	30.6
	931.5	1656	923.5	0.991	1907	*1.143*	0	243	35.4	922.5	0.990	1914	*1.147*	1	221	29.1
	2372.8	1571	2562.6	*1.080*	1799	*1.136*	0	257	32.0	2643.2	*1.114*	2724	*1.690*	0	365	26.3
	1908.0	2158	4152.5	*2.176*	3677	*1.673*	0	378	38.4	767.1	**0.402**	1462	**0.692**	0	88	27.0
netdiversion	1107.0	55	1104.4	0.998	59	1.026	1	0	993.0	1553.8	*1.403*	68	*1.084*	0	0	993.0
	2874.7	75	2575.6	**0.896**	66	**0.949**	0	0	187.0	2568.8	**0.894**	66	**0.949**	0	0	166.0
	6390.9	149	4748.0	**0.743**	261	*1.450*	1	13	898.7	6359.6	0.995	140	0.964	0	11	1083.0
	1042.8	27	1044.2	1.001	26	0.992	0	1	9.0	1054.8	1.011	27	1.000	0	3	11.0
newdano	limit	1264180	limit	1.000	1232571	0.975	0	9	21.9	limit	1.000	1286241	1.017	0	3	31.2
	limit	1124180	limit	1.000	1299616	*1.156*	0	1	22.1	limit	1.000	1175614	1.046	0	1	30.6
	limit	1151118	limit	1.000	1138354	0.989	0	5	21.8	limit	1.000	1114040	0.968	1	2	27.2
	limit	1368041	limit	1.000	1346166	0.984	2	12	21.6	limit	1.000	1487867	*1.088*	0	1	30.1
noswot	319.4	930332	283.1	**0.887**	813210	**0.874**	0	521	29.6	255.1	**0.799**	775820	**0.834**	0	372	30.3
	209.1	638764	197.4	**0.944**	590698	**0.925**	0	580	29.2	197.8	**0.946**	627162	0.982	0	341	29.5
	368.2	1222044	291.7	**0.793**	919828	**0.753**	0	1458	27.9	133.5	**0.364**	384877	**0.315**	0	703	26.3
	184.9	547512	272.9	*1.473*	856222	*1.564*	0	752	28.1	190.9	1.032	574094	1.049	0	678	27.7
ns1208400	852.0	2184	1315.5	*1.543*	3332	*1.503*	0	46	209.0	315.3	**0.371**	407	**0.222**	0	10	38.2
	1039.1	2266	399.3	**0.385**	827	**0.392**	0	8	376.5	595.8	**0.574**	1887	**0.840**	0	217	58.0
	356.4	2042	302.3	**0.849**	2522	*1.224*	0	443	157.9	214.8	**0.604**	587	**0.321**	0	135	90.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	1540.7	3819	632.8	**0.411**	2476	**0.657**	0	31	363.6	1972.6	*1.280*	7823	*2.022*	0	159	128.2
ns1688347	46.7	239	47.1	1.009	254	1.044	0	10	23.0	46.7	0.999	219	**0.941**	0	14	36.0
	85.9	945	70.2	**0.820**	688	**0.754**	0	339	36.6	68.7	**0.802**	693	**0.759**	0	393	20.4
	195.5	1567	182.9	**0.936**	1063	**0.698**	0	599	31.9	177.3	**0.907**	980	**0.648**	0	344	27.0
	55.2	454	63.9	*1.156*	660	*1.372*	0	160	35.4	56.3	1.019	487	*1.060*	0	91	18.6
ns1758913	5203.3	2	5142.5	0.988	2	1.000	0	0	0.0	5158.0	0.991	2	1.000	0	0	0.0
	2089.2	1	2115.3	1.012	1	1.000	0	0	0.0	2084.0	0.997	1	1.000	0	0	0.0
	2234.6	1	2219.4	0.993	1	1.000	0	0	0.0	2201.7	0.985	1	1.000	0	0	0.0
	1487.7	1	1490.2	1.002	1	1.000	0	0	0.0	1491.3	1.002	1	1.000	0	0	0.0
ns1766074	816.4	890073	806.8	0.988	889034	0.999	0	184	31.1	818.2	1.002	887883	0.998	0	343	29.6
	880.1	899379	916.1	1.041	904416	1.006	0	417	29.9	900.5	1.023	898389	0.999	0	453	30.2
	807.0	902001	807.6	1.001	901625	1.000	0	154	29.8	800.5	0.992	901502	0.999	0	226	30.8
	910.7	901843	902.7	0.991	902421	1.001	0	363	30.2	935.2	1.027	902125	1.000	0	353	30.9
ns1830653	358.9	19335	245.5	**0.685**	11159	**0.579**	0	973	30.7	201.9	**0.564**	9374	**0.487**	0	1789	21.9
	164.9	5757	132.1	**0.802**	4245	**0.742**	1	547	42.6	142.7	**0.866**	4047	**0.708**	1	328	26.6
	132.0	5316	177.6	*1.343*	7106	*1.331*	0	1026	37.1	155.6	*1.177*	5127	0.965	0	965	25.0
	193.9	8257	183.2	**0.945**	4909	**0.599**	0	370	40.8	134.6	**0.696**	4326	**0.530**	0	563	23.4
nsa	2.3	232	2.6	*1.110*	226	0.982	0	0	10.0	2.3	1.009	232	1.000	0	0	0.0
	2.3	198	2.2	0.963	212	1.047	0	0	9.5	2.4	1.027	198	1.000	0	0	9.0
	2.3	209	2.2	0.997	191	**0.942**	0	0	10.0	2.3	1.000	209	1.000	0	0	0.0
	2.3	203	2.4	1.033	217	1.046	0	0	9.0	2.4	1.009	203	1.000	0	0	9.0
nsrand-ipx	632.3	65551	720.5	*1.139*	83815	*1.278*	0	19	84.4	361.5	**0.572**	36235	**0.553**	0	8	115.8
	766.8	84144	712.2	**0.929**	73290	**0.871**	0	36	92.0	722.3	**0.942**	59686	**0.710**	0	24	132.7
	455.1	40237	1094.1	*2.401*	113654	*2.820*	0	52	93.9	376.5	**0.828**	32679	**0.813**	0	10	122.2
	750.3	70493	444.8	**0.593**	41859	**0.594**	0	29	80.9	590.4	**0.787**	57642	**0.818**	0	11	123.0
nug08	146.4	3	146.1	0.998	3	1.000	0	0	0.0	146.1	0.998	3	1.000	0	0	0.0
	93.7	2	93.5	0.999	2	1.000	0	0	0.0	93.4	0.997	2	1.000	0	0	0.0
	209.9	4	209.3	0.997	4	1.000	0	0	0.0	209.3	0.997	4	1.000	0	0	0.0
	136.2	2	136.3	1.001	2	1.000	0	0	0.0	136.1	0.999	2	1.000	0	0	0.0
nw04	25.0	6	25.0	1.001	6	1.000	0	0	0.0	25.1	1.003	6	1.000	0	0	0.0
	25.8	6	25.8	1.001	6	1.000	0	0	0.0	25.9	1.004	6	1.000	0	0	0.0
	25.2	4	27.5	*1.088*	6	1.019	0	0	0.0	25.2	1.000	4	1.000	0	0	0.0
	38.6	9	38.7	1.001	9	1.000	0	0	0.0	39.0	1.009	9	1.000	0	0	0.0
opm2-z7-s2	344.2	2699	418.8	*1.216*	3782	*1.387*	0	91	39.9	388.2	*1.127*	3063	*1.130*	0	0	42.2
	321.9	1726	269.8	**0.839**	1576	**0.918**	0	0	18.0	265.2	**0.825**	1651	0.959	0	17	41.3
	330.0	2369	323.0	0.979	1537	**0.663**	0	179	49.5	403.2	*1.221*	3830	*1.592*	1	58	58.4

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Table D.2: Computational results on MMMC: CONFLICT DIVING

Instance	nolockdiving		coefdiving							confdiving						
	T	**N**	**T**	**T$_Q$**	**N**	**N$_Q$**	**F**	**C**	**D$_\emptyset$**	**T**	**T$_Q$**	**N**	**N$_Q$**	**F**	**C**	**D$_\emptyset$**
	298.2	1934	323.2	*1.084*	2091	*1.077*	0	122	46.5	274.1	**0.920**	1800	**0.934**	0	28	47.8
opt1217	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
p0033	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
p0201	0.7	3	0.6	0.988	3	1.000	0	0	0.0	0.7	0.994	3	1.000	0	0	0.0
	0.9	9	0.9	1.005	9	1.000	0	0	0.0	0.9	1.010	9	1.000	0	0	0.0
	0.9	9	0.9	0.990	9	1.000	0	0	0.0	0.9	1.005	9	1.000	0	0	0.0
	0.8	11	0.8	1.023	11	1.000	0	0	0.0	0.8	1.034	11	1.000	0	0	0.0
p0282	0.7	2	0.6	0.970	2	1.000	0	0	0.0	0.7	1.048	2	1.000	0	0	0.0
	0.6	2	0.6	1.019	2	1.000	0	0	0.0	0.6	1.038	2	1.000	0	0	0.0
	0.8	3	0.9	1.039	3	1.000	0	0	0.0	0.8	1.022	3	1.000	0	0	0.0
	0.8	2	0.7	0.956	2	1.000	0	0	0.0	0.7	0.961	2	1.000	0	0	0.0
p0548	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
p2756	5.4	8	6.3	*1.148*	5	0.972	0	0	0.0	4.2	**0.819**	17	*1.083*	0	1	16.0
	4.3	14	3.4	**0.823**	3	**0.904**	0	0	0.0	3.6	**0.874**	24	*1.088*	0	0	26.0
	4.3	30	4.5	1.028	27	0.977	0	1	11.0	4.2	0.972	19	**0.915**	0	0	0.0
	3.1	2	3.2	1.032	5	1.029	0	0	0.0	2.6	**0.889**	2	1.000	0	0	0.0
p6b	limit	512757	limit	1.000	550754	*1.074*	1	560	26.5	limit	1.000	510159	0.995	0	201	26.9
	limit	596175	limit	1.000	576187	0.966	3	233	28.6	limit	1.000	599594	1.006	0	139	28.5
	limit	620224	limit	1.000	550144	**0.887**	3	299	32.7	limit	1.000	561442	**0.905**	0	166	32.2
	limit	581618	limit	1.000	557843	0.959	0	62	25.5	limit	1.000	510044	**0.877**	0	118	27.0
pg5_34	5628.2	252176	5920.9	*1.052*	238659	**0.946**	0	1	51.5	5625.5	1.000	228356	**0.906**	0	1	31.9
	1281.3	221050	1478.6	*1.154*	236000	*1.068*	0	0	48.1	1458.4	*1.138*	233600	*1.057*	0	0	29.7
	3294.3	202592	4595.4	*1.395*	225680	*1.114*	0	0	43.3	4017.6	*1.219*	227448	*1.123*	0	0	33.4
	4094.8	223003	4039.3	0.986	234406	*1.051*	1	0	46.7	3654.1	**0.892**	221932	0.995	0	0	32.0
pg	20.0	688	22.2	*1.106*	840	*1.193*	0	0	29.0	22.1	*1.097*	834	*1.185*	0	1	29.1
	31.6	516	34.1	*1.076*	599	*1.135*	0	0	24.0	33.5	*1.057*	615	*1.161*	0	0	33.9
	29.3	584	30.7	1.044	610	1.038	0	0	34.4	27.9	0.953	518	**0.904**	0	1	29.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	19.5	182	19.9	1.018	195	1.046	0	2	24.3	19.8	1.015	189	1.025	0	2	19.3
pigeon-10	limit	15401832	5879.0	**0.817**	13529494	**0.878**	0	1986	29.1	5880.0	**0.817**	13430733	**0.872**	0	2043	30.0
	limit	17278475	limit	1.000	16585536	0.960	0	4725	29.4	limit	1.000	16371694	**0.948**	0	4323	28.3
	5952.4	13415056	7093.8	*1.192*	13405990	0.999	0	6026	26.9	5979.6	1.005	13639826	1.017	0	2499	27.6
	5829.3	13635194	5763.9	0.989	13640551	1.000	0	1794	27.5	5714.8	0.980	13623257	0.999	0	1539	27.7
pk1	130.7	329300	126.3	0.967	328666	0.998	0	55	28.3	131.3	1.004	341221	1.036	0	44	26.4
	120.2	316905	136.0	*1.130*	344203	*1.086*	0	37	27.5	118.8	0.988	310944	0.981	0	38	27.9
	117.3	298403	124.4	*1.060*	319169	*1.070*	0	45	28.1	132.8	*1.131*	348833	*1.169*	0	29	29.1
	115.7	299208	134.9	*1.165*	342753	*1.145*	0	62	27.5	134.5	*1.161*	334026	*1.116*	0	41	28.8
pp08a	2.3	257	2.9	*1.188*	282	*1.070*	0	0	26.0	2.5	*1.052*	282	*1.070*	0	0	26.0
	2.1	287	2.2	1.025	269	0.953	0	2	26.0	2.2	1.022	269	0.953	0	2	26.0
	2.3	207	2.1	**0.940**	164	**0.860**	1	3	26.0	2.1	**0.922**	164	**0.860**	1	3	26.0
	1.6	118	1.5	0.992	116	0.991	0	2	26.0	1.6	1.020	116	0.991	0	2	26.0
pp08aCUTS	2.6	180	3.4	*1.204*	329	*1.532*	0	2	23.0	3.0	*1.096*	329	*1.532*	0	2	23.0
	2.7	164	3.0	*1.090*	282	*1.447*	0	4	29.0	2.9	*1.071*	282	*1.447*	0	4	30.0
	2.5	252	2.5	1.006	250	0.994	0	1	26.0	2.6	1.023	325	*1.207*	1	2	35.0
	2.8	291	2.8	0.984	226	**0.834**	0	5	24.0	2.7	0.963	226	**0.834**	0	3	24.0
prod1	32.2	35022	27.3	**0.852**	30227	**0.863**	0	573	36.6	25.6	**0.801**	28403	**0.812**	0	422	34.9
	28.5	28250	27.7	0.972	28677	1.015	0	657	35.7	32.6	*1.138*	33204	*1.175*	0	797	35.2
	22.6	22944	20.9	**0.929**	22822	0.995	0	348	36.8	20.8	**0.925**	23358	1.018	0	424	37.8
	21.1	22434	21.6	1.023	22930	1.022	0	322	37.0	21.5	1.021	22738	1.013	0	408	35.9
prod2	152.7	112488	148.7	0.974	107994	0.960	0	465	46.0	134.8	**0.883**	92635	**0.824**	0	789	45.8
	limit	2189138	104.4	**0.015**	71063	**0.033**	0	860	44.5	105.8	**0.015**	81993	**0.037**	0	492	45.7
	113.6	95391	110.4	0.971	91488	0.959	0	824	44.8	148.0	*1.300*	111992	*1.174*	0	358	44.8
	164.1	123369	138.6	**0.846**	108421	**0.879**	0	743	45.2	135.2	**0.825**	101941	**0.826**	0	513	45.5
protfold	limit	11471	limit	1.000	8197	**0.717**	0	188	49.3	limit	1.000	8675	**0.758**	0	147	196.5
	limit	10374	limit	1.000	8406	**0.812**	0	325	35.6	limit	1.000	9150	**0.883**	0	186	215.2
	limit	14631	limit	1.000	11977	**0.820**	0	261	37.7	limit	1.000	10005	**0.686**	0	41	105.0
	limit	12858	limit	1.000	15524	*1.206*	0	493	45.1	limit	1.000	9325	**0.727**	0	280	178.2
pw-myciel4	1359.7	161995	749.7	**0.552**	90247	**0.557**	1	6613	45.4	940.7	**0.692**	113552	**0.701**	0	8979	29.3
	1778.5	188895	2870.5	*1.614*	348714	*1.846*	1	25218	54.9	2390.3	*1.344*	234994	*1.244*	1	5679	40.3
	5296.8	456333	limit	*1.359*	591631	*1.296*	1	13939	60.2	limit	*1.359*	701701	*1.538*	1	17500	36.8
	4087.4	395115	2575.4	**0.630**	238039	**0.603**	0	12511	61.7	2323.8	**0.569**	217796	**0.551**	0	7173	36.3
qap10	87.5	5	87.0	0.995	5	1.000	0	0	0.0	86.9	0.993	5	1.000	0	0	0.0
	132.8	2	133.0	1.001	2	1.000	0	0	0.0	133.1	1.003	2	1.000	0	0	0.0
	220.3	14	220.2	1.000	14	1.000	0	0	18.0	220.3	1.000	14	1.000	0	0	18.0

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	95.8	3	94.8	0.989	3	1.000	0	0	0.0	94.6	0.988	3	1.000	0	0	0.0
qiu	37.0	3988	38.8	1.045	3841	0.964	1	9	22.5	38.8	1.045	3897	0.978	3	6	26.6
	20.2	1911	21.4	*1.059*	2142	*1.115*	2	4	25.3	20.1	0.997	1961	1.025	3	3	28.0
	40.5	3815	40.9	1.012	4087	*1.069*	3	12	27.5	43.2	*1.067*	4127	*1.080*	3	14	22.5
	46.2	4295	47.1	1.021	4325	1.007	0	7	22.2	56.8	*1.226*	5273	*1.223*	2	11	29.7
qnet1	5.2	24	6.3	*1.181*	29	1.040	0	0	108.0	5.9	*1.110*	29	1.040	0	0	108.0
	9.8	5	9.8	1.007	5	1.000	0	0	0.0	9.8	1.007	5	1.000	0	0	0.0
	2.4	2	2.6	*1.062*	2	1.000	0	0	0.0	2.4	0.994	2	1.000	0	0	0.0
	5.5	24	5.6	1.011	24	1.000	0	0	0.0	5.5	0.997	24	1.000	0	0	0.0
qnet1_o	2.9	3	2.4	**0.886**	3	1.000	0	0	0.0	2.7	0.966	3	1.000	0	0	0.0
	3.5	12	3.5	0.987	12	1.000	0	0	0.0	3.5	0.991	12	1.000	0	0	0.0
	1.2	2	1.2	0.991	2	1.000	0	0	0.0	1.3	1.018	2	1.000	0	0	0.0
	1.4	1	1.4	1.004	1	1.000	0	0	0.0	1.4	0.992	1	1.000	0	0	0.0
rail507	215.7	651	187.3	**0.869**	631	0.973	0	0	206.0	210.5	0.976	679	1.037	0	1	225.5
	240.8	828	227.2	**0.944**	807	0.977	0	0	193.5	239.6	0.995	801	0.971	0	0	222.0
	276.1	999	288.9	1.046	900	**0.910**	0	1	215.5	248.2	**0.899**	863	**0.876**	0	1	207.2
	259.9	930	247.0	0.951	847	**0.919**	0	3	220.5	322.4	*1.240*	1024	*1.091*	0	3	224.8
ramos3	limit	29	limit	1.000	29	1.000	0	0	337.0	limit	1.000	29	1.000	0	0	0.0
	limit	31	limit	1.000	29	0.985	0	0	337.0	limit	1.000	31	1.000	0	0	0.0
	limit	32	limit	1.000	32	1.000	0	0	337.0	limit	1.000	32	1.000	0	0	0.0
	limit	29	limit	1.000	29	1.000	0	0	337.0	limit	1.000	29	1.000	0	0	0.0
ran14x18.disj-8	2238.1	628002	2069.9	**0.925**	422669	**0.673**	0	23	55.2	2456.9	*1.098*	549355	**0.875**	0	44	58.8
	2357.4	572434	2209.9	**0.937**	509529	**0.890**	0	28	58.1	2460.1	1.044	566927	0.990	0	23	57.0
	2509.8	608217	3662.1	*1.459*	791360	*1.301*	0	35	57.4	4002.8	*1.595*	789688	*1.298*	0	50	55.7
	2282.1	430341	4787.8	*2.098*	511977	*1.190*	0	31	55.5	3561.4	*1.560*	780869	*1.814*	0	33	57.2
ran14x18_1	1312.9	322042	1492.9	*1.137*	339134	*1.053*	0	39	55.4	2070.9	*1.577*	489131	*1.519*	0	34	57.1
	1495.9	385773	1704.0	*1.139*	418898	*1.086*	0	29	51.7	1829.4	*1.223*	513172	*1.330*	0	55	54.7
	1345.7	408436	1837.9	*1.365*	497943	*1.219*	0	30	52.7	1239.7	**0.921**	361065	**0.884**	0	46	52.4
	1413.1	549906	2404.9	*1.701*	769180	*1.399*	0	55	56.6	2942.5	*2.082*	827086	*1.504*	0	59	58.8
ran16x16	114.4	12752	104.2	**0.911**	14539	*1.139*	0	26	47.3	129.6	*1.131*	17386	*1.361*	0	8	46.5
	103.6	14523	104.6	1.009	15549	*1.070*	0	23	42.8	103.0	0.994	11000	**0.759**	0	32	45.2
	77.6	8834	81.3	1.047	7934	**0.899**	0	10	44.9	87.6	*1.127*	10745	*1.214*	0	20	47.4
	86.5	12562	98.9	*1.142*	11547	**0.920**	0	22	48.9	93.7	*1.082*	8170	**0.653**	0	30	44.6
rd-rplusc-21	limit	367652	limit	1.000	567874	*1.544*	0	39	83.8	limit	1.000	550245	*1.497*	0	25	70.2
	limit	687233	limit	1.000	721961	*1.051*	0	16	106.4	limit	1.000	599858	**0.873**	0	0	93.5
	limit	658620	limit	1.000	650647	0.988	0	35	89.3	limit	1.000	556992	**0.846**	0	134	65.8

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	941736	limit	1.000	1062288	*1.128*	0	178	78.1	limit	1.000	939185	0.997	0	352	76.2
reblock67	283.4	34650	287.8	1.015	40539	*1.169*	0	1634	48.3	330.1	*1.164*	41226	*1.189*	1	2128	50.0
	208.5	42286	254.6	*1.220*	52781	*1.248*	0	4012	43.9	316.5	*1.516*	71874	*1.698*	0	1290	38.5
	295.1	55204	308.0	1.044	53944	0.977	0	3655	45.2	248.8	**0.844**	44733	**0.811**	1	1004	46.3
	276.9	52907	282.9	1.022	56714	*1.072*	1	2447	43.9	276.3	0.998	55239	1.044	1	2872	42.1
rentacar	3.1	4	2.8	**0.917**	4	1.000	0	0	0.0	3.2	1.032	4	1.000	0	0	0.0
	2.7	2	2.8	1.014	2	1.000	0	0	0.0	2.7	0.995	2	1.000	0	0	0.0
	3.0	16	3.0	0.998	16	1.000	1	0	7.0	3.0	0.993	16	1.000	1	0	7.0
	2.8	14	2.8	1.019	14	1.000	1	0	5.0	2.8	1.008	14	1.000	1	0	5.0
rgn	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.6	1.033	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
rlp1	limit	24200467	limit	1.000	23496354	0.971	0	29897	60.5	limit	1.000	22282217	**0.921**	0	23571	59.3
	limit	23816302	limit	1.000	23862299	1.002	0	37447	60.9	limit	1.000	23340880	0.980	0	40321	59.9
	limit	19651080	limit	1.000	19988711	1.017	0	30309	60.2	limit	1.000	19684912	1.002	0	30257	56.4
	limit	24955525	limit	1.000	26058509	1.044	0	35346	59.1	limit	1.000	26734290	*1.071*	0	23220	58.7
rmatr100-p10	192.0	790	186.2	0.970	820	1.034	0	2	38.7	184.7	0.962	806	1.018	0	4	40.0
	198.4	779	197.8	0.997	807	1.032	0	5	35.6	194.6	0.981	822	1.049	0	3	41.1
	185.8	787	189.3	1.019	846	*1.067*	0	2	31.7	189.8	1.021	835	*1.054*	0	9	39.2
	192.3	769	201.2	1.046	852	*1.096*	0	3	38.6	195.0	1.014	774	1.006	0	5	38.8
rmatr100-p5	332.3	383	344.6	1.037	365	0.963	0	2	44.0	339.9	1.023	361	0.954	0	1	35.5
	309.6	417	344.6	*1.113*	409	0.985	0	1	33.7	370.5	*1.196*	435	1.035	0	2	29.0
	346.1	427	324.9	**0.939**	449	1.042	0	2	37.0	355.7	1.028	433	1.011	0	0	34.3
	311.0	407	347.9	*1.119*	405	0.996	0	0	40.5	327.0	*1.051*	381	**0.949**	0	0	38.5
rmine6	1101.5	80935	1034.2	**0.939**	76215	**0.942**	0	249	58.4	1054.6	0.957	76454	**0.945**	0	173	58.4
	980.5	67361	1077.5	*1.099*	60737	**0.902**	0	16	62.8	959.3	0.978	73889	*1.097*	0	427	50.1
	857.8	74032	1372.4	*1.599*	121375	*1.639*	0	485	63.1	1199.9	*1.398*	105615	*1.426*	0	648	59.9
	972.7	86062	1116.4	*1.148*	101031	*1.174*	0	258	59.4	1036.3	*1.065*	75633	**0.879**	0	336	55.7
rocII-4-11	1830.1	6754	1738.5	**0.950**	4087	**0.611**	0	302	35.8	2167.3	*1.184*	14126	*2.076*	2	1773	21.0
	2128.2	11498	1606.1	**0.755**	4222	**0.373**	5	907	24.8	1911.8	**0.898**	6571	**0.575**	0	236	20.4
	2186.4	11600	2148.4	0.983	7462	**0.646**	3	840	28.1	2230.2	1.020	12526	*1.079*	0	918	20.7
	2494.6	12543	2263.4	**0.907**	13470	*1.073*	0	203	33.5	2078.1	**0.833**	10869	**0.868**	1	755	18.8
rococoC10-001000	2167.2	204524	2090.1	0.964	153256	**0.749**	0	182	125.9	1839.0	**0.849**	125976	**0.616**	0	298	106.8
	1204.4	70056	1301.2	*1.080*	75594	*1.079*	0	220	110.9	828.0	**0.688**	50620	**0.723**	0	219	109.5
	765.6	40706	534.1	**0.698**	29811	**0.733**	0	115	101.2	1254.8	*1.638*	67377	*1.654*	0	419	99.9

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Table D.2: Computational results on MMMC: CONFLICT DIVING

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	715.7	40137	1136.7	*1.587*	56599	*1.409*	0	21	109.6	970.0	*1.355*	53645	*1.336*	0	2	87.0
roll3000	43.2	1323	42.1	0.974	1664	*1.240*	0	3	39.0	42.8	0.990	1591	*1.188*	0	13	67.0
	71.0	3118	82.4	*1.158*	4508	*1.432*	0	43	82.2	84.2	*1.183*	4305	*1.369*	0	70	65.6
	56.9	2433	41.7	**0.737**	1440	**0.608**	0	15	85.5	50.1	**0.882**	1846	**0.768**	0	28	78.5
	69.5	3012	101.8	*1.459*	4486	*1.474*	0	98	88.7	87.5	*1.256*	3336	*1.104*	0	62	76.1
rout	72.3	13008	79.0	*1.090*	15767	*1.210*	0	32	36.6	88.4	*1.219*	16241	*1.247*	0	132	27.1
	96.0	17125	102.1	*1.062*	20064	*1.171*	0	19	43.2	86.1	**0.897**	16862	0.985	0	149	32.7
	80.0	15827	73.6	**0.921**	13081	**0.828**	0	41	40.8	91.7	*1.145*	17858	*1.128*	0	40	31.5
	58.5	10429	78.1	*1.329*	12730	*1.219*	1	53	41.3	66.6	*1.136*	14419	*1.379*	3	446	30.4
roy	0.5	2	0.5	1.000	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	2	0.5	1.000	2	1.000	0	0	0.0	0.5	1.000	2	1.000	0	0	0.0
satellites1-25	1054.5	2416	1105.4	1.048	2376	0.984	1	7	17.2	818.9	**0.777**	1145	**0.495**	0	18	16.5
	1372.8	2322	860.8	**0.627**	817	**0.379**	1	11	25.0	1254.0	**0.913**	1451	**0.640**	0	8	18.0
	1191.4	1235	1441.9	*1.210*	2878	*2.231*	0	41	21.5	1613.4	*1.354*	3475	*2.678*	0	60	27.8
	1404.7	1753	1187.2	**0.845**	1159	**0.679**	1	38	32.0	956.2	**0.681**	569	**0.361**	0	16	28.7
set1ch	0.9	1	0.8	0.989	1	1.000	0	0	0.0	0.9	1.000	1	1.000	0	0	0.0
	0.7	1	0.6	0.976	1	1.000	0	0	0.0	0.6	0.976	1	1.000	0	0	0.0
	0.6	1	0.6	1.006	1	1.000	0	0	0.0	0.6	1.006	1	1.000	0	0	0.0
	0.7	2	0.6	0.970	2	1.000	0	0	0.0	0.7	1.000	2	1.000	0	0	0.0
seymour.disj-10	limit	69639	limit	1.000	62861	**0.903**	0	24	102.2	limit	1.000	75331	*1.082*	0	51	106.3
	limit	73827	limit	1.000	70642	0.957	0	96	107.5	limit	1.000	72132	0.977	0	21	107.9
	limit	75099	limit	1.000	75736	1.008	0	82	107.8	limit	1.000	57540	**0.766**	0	20	118.4
	limit	60045	limit	1.000	73003	*1.215*	0	121	103.4	limit	1.000	65272	*1.087*	0	24	111.0
seymour	limit	191497	limit	1.000	125851	**0.657**	0	298	92.0	limit	1.000	188464	0.984	0	474	93.7
	limit	199159	limit	1.000	209286	*1.051*	0	259	88.3	limit	1.000	202546	1.017	0	168	99.2
	limit	199729	limit	1.000	202751	1.015	0	72	85.1	limit	1.000	183033	**0.916**	0	626	90.9
	limit	166399	limit	1.000	177194	*1.065*	0	149	88.1	limit	1.000	196212	*1.179*	0	396	109.2
sp97ar	limit	16135	limit	1.000	20888	*1.293*	0	0	0.0	limit	1.000	18942	*1.173*	0	0	0.0
	limit	19101	limit	1.000	17965	**0.941**	0	0	0.0	limit	1.000	18484	0.968	0	0	0.0
	limit	23655	limit	1.000	23126	0.978	0	0	0.0	limit	1.000	21789	**0.921**	0	0	0.0
	limit	16608	limit	1.000	22922	*1.378*	0	0	0.0	limit	1.000	18305	*1.102*	0	0	0.0
sp97ic	limit	23572	limit	1.000	26114	*1.107*	0	13	44.8	limit	1.000	36904	*1.563*	0	12	148.2
	limit	41029	limit	1.000	43908	*1.070*	0	0	50.0	limit	1.000	35236	**0.859**	0	0	116.5
	limit	49004	limit	1.000	39496	**0.806**	0	0	11.0	limit	1.000	21333	**0.436**	0	12	101.2

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving							confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	21935	limit	1.000	21179	0.966	0	14	37.8	limit	1.000	32024	*1.458*	0	30	133.0
sp98ar	limit	2151	limit	1.000	2459	*1.137*	0	0	104.0	limit	1.000	2451	*1.133*	0	0	271.0
	limit	2442	limit	1.000	2326	0.954	1	0	90.5	limit	1.000	2621	*1.070*	0	5	352.0
	limit	2458	limit	1.000	2384	0.971	1	0	74.5	limit	1.000	2688	*1.090*	0	3	257.5
	limit	3508	limit	1.000	2469	**0.712**	1	0	90.0	limit	1.000	2457	**0.709**	0	2	114.0
sp98ic	limit	45351	limit	1.000	50578	*1.115*	0	0	148.0	limit	1.000	49042	*1.081*	0	0	79.0
	limit	49103	limit	1.000	35833	**0.730**	0	0	74.0	limit	1.000	34379	**0.701**	0	0	118.2
	limit	63125	limit	1.000	49177	**0.779**	0	0	18.0	limit	1.000	36765	**0.583**	0	0	136.0
	limit	34818	limit	1.000	45789	*1.314*	0	0	154.7	limit	1.000	39709	*1.140*	0	0	124.2
sp98ir	72.7	3543	90.6	*1.243*	3218	**0.911**	0	16	30.6	95.2	*1.307*	5250	*1.469*	0	21	55.0
	93.8	3831	84.8	**0.906**	4935	*1.281*	0	79	39.5	84.2	**0.899**	4342	*1.130*	0	0	43.8
	62.6	3212	83.7	*1.332*	5009	*1.543*	0	58	40.6	88.7	*1.411*	4559	*1.407*	1	0	60.2
	90.8	5440	70.5	**0.779**	4424	**0.817**	0	12	37.2	71.7	**0.792**	3477	**0.646**	0	25	48.0
stein27	1.2	1155	1.2	1.023	1171	1.013	0	0	14.3	1.3	1.041	1191	1.029	0	0	14.7
	1.3	1729	1.3	0.991	1785	1.031	0	0	13.9	1.4	1.030	1819	1.049	0	0	14.6
	0.6	515	0.6	0.975	537	1.036	0	0	14.8	0.6	0.988	555	*1.065*	0	0	15.2
	0.7	597	0.7	1.030	699	*1.146*	0	0	15.3	0.7	1.024	673	*1.109*	0	0	14.6
stein45	17.3	39479	17.9	1.032	41379	1.048	0	0	15.8	17.4	1.008	39479	1.000	0	0	0.0
	17.3	37653	18.2	1.050	40886	*1.086*	0	0	16.4	17.6	1.019	37653	1.000	0	0	0.0
	18.2	39670	18.0	0.988	38979	0.983	0	0	16.0	18.4	1.009	39670	1.000	0	0	0.0
	18.1	40621	18.9	1.043	41223	1.015	0	0	15.4	19.0	1.047	40621	1.000	0	0	0.0
stp3d	limit	15	limit	1.000	15	1.000	0	0	0.0	limit	1.000	15	1.000	0	0	0.0
	limit	13	limit	1.000	12	0.991	0	0	0.0	limit	1.000	13	1.000	0	0	0.0
	limit	15	limit	1.000	15	1.000	0	0	0.0	limit	1.000	15	1.000	0	0	0.0
	limit	14	limit	1.000	14	1.000	0	0	0.0	limit	1.000	14	1.000	0	0	0.0
swath	limit	531431	limit	1.000	409009	**0.770**	0	31	55.2	limit	1.000	630971	*1.187*	0	165	62.2
	limit	637741	limit	1.000	318991	**0.500**	0	15	82.1	limit	1.000	494509	**0.775**	0	248	52.7
	limit	569638	limit	1.000	314999	**0.553**	0	306	64.7	limit	1.000	430119	**0.755**	0	206	61.7
	limit	377720	limit	1.000	310822	**0.823**	0	101	65.0	limit	1.000	364533	0.965	0	275	55.7
t1717	limit	3781	limit	1.000	3114	**0.828**	0	0	429.7	limit	1.000	4131	*1.090*	0	356	61.3
	limit	3685	limit	1.000	4269	*1.154*	0	0	418.0	limit	1.000	4077	*1.104*	0	425	86.1
	limit	4215	limit	1.000	4129	0.980	0	0	422.7	limit	1.000	4274	1.014	0	912	79.5
	limit	3775	limit	1.000	4126	*1.091*	0	0	392.5	limit	1.000	3451	**0.916**	0	397	103.2
tanglegram1	686.7	53	717.6	1.045	53	1.000	0	0	1118.0	687.7	1.001	53	1.000	0	0	18.0
	1006.3	113	1022.2	1.016	117	1.019	0	0	17.0	1022.7	1.016	117	1.019	0	0	83.0
	845.5	71	830.6	0.982	75	1.023	0	11	16.0	840.8	0.994	71	1.000	0	0	130.0

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Table D.2: Computational results on MMMC: CONFLICT DIVING

Instance	nolockdiving		coefdiving							confdiving						
	T	**N**	**T**	**T**$_Q$	**N**	**N**$_Q$	**F**	**C**	**D**$_\emptyset$	**T**	**T**$_Q$	**N**	**N**$_Q$	**F**	**C**	**D**$_\emptyset$
	696.5	61	694.5	0.997	61	1.000	0	0	23.0	701.2	1.007	61	1.000	0	0	105.0
tanglegram2	7.4	3	7.3	0.987	3	1.000	0	0	0.0	7.3	0.988	3	1.000	0	0	0.0
	6.7	3	6.7	1.009	3	1.000	0	0	0.0	6.8	1.017	3	1.000	0	0	0.0
	7.0	3	7.0	1.001	3	1.000	0	0	0.0	7.0	0.998	3	1.000	0	0	0.0
	7.2	3	7.1	0.999	3	1.000	0	0	0.0	7.1	0.999	3	1.000	0	0	0.0
timtab1	61.5	37362	77.8	*1.260*	49976	*1.337*	0	76	40.8	69.5	*1.127*	43028	*1.151*	0	56	39.7
	56.9	30500	53.0	**0.933**	30772	1.009	0	77	38.4	76.0	*1.330*	49194	*1.611*	1	204	31.8
	64.2	42359	70.0	*1.088*	44702	*1.055*	1	112	39.4	71.8	*1.116*	45146	*1.066*	0	127	34.1
	60.2	41683	59.8	0.992	39788	0.955	0	66	40.2	59.6	0.989	36689	**0.880**	1	236	33.8
timtab2	limit	2568006	limit	1.000	2405695	**0.937**	0	252	43.5	limit	1.000	2428579	**0.946**	1	423	45.3
	limit	2239971	limit	1.000	2161489	0.965	0	242	44.1	limit	1.000	2467893	*1.102*	0	291	40.6
	limit	2796654	limit	1.000	3063738	*1.095*	0	237	46.0	limit	1.000	2281198	**0.816**	0	237	44.0
	limit	3340774	limit	1.000	2201097	**0.659**	0	294	45.4	limit	1.000	2374633	**0.711**	0	356	41.4
tr12-30	783.0	365013	1031.9	*1.317*	520717	*1.426*	0	172	48.4	1034.2	*1.320*	519436	*1.423*	0	131	50.1
	692.3	357383	923.2	*1.333*	462981	*1.295*	0	417	52.1	737.5	*1.065*	359200	1.005	0	255	52.6
	680.8	293580	1275.8	*1.873*	595373	*2.028*	0	88	54.7	836.0	*1.228*	369143	*1.257*	0	67	58.5
	670.3	248694	718.1	*1.071*	309327	*1.244*	0	83	49.4	872.5	*1.301*	385231	*1.549*	0	46	52.4
triptim1	1558.8	7	1552.9	0.996	7	1.000	0	0	0.0	1562.1	1.002	7	1.000	0	0	0.0
	841.2	8	839.4	0.998	8	1.000	0	0	0.0	839.0	0.997	8	1.000	0	0	0.0
	590.6	4	586.5	0.993	4	1.000	0	0	0.0	588.5	0.996	4	1.000	0	0	0.0
	1579.5	151	1074.9	**0.681**	41	**0.562**	0	0	37.0	1187.8	**0.752**	41	**0.562**	0	8	38.0
unitcal_7	416.0	149	367.9	**0.885**	155	1.024	0	0	21.0	425.3	1.022	143	0.976	0	0	24.0
	437.7	294	508.6	*1.162*	356	*1.157*	0	0	40.7	346.3	**0.792**	196	**0.751**	0	0	22.0
	573.5	580	564.2	0.984	377	**0.701**	0	0	51.5	391.9	**0.684**	182	**0.415**	0	0	22.0
	664.6	815	506.7	**0.763**	572	**0.734**	0	3	46.7	585.0	**0.880**	742	**0.920**	0	0	33.8
vpm1	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
	0.5	1	0.5	1.000	1	1.000	0	0	0.0	0.5	1.000	1	1.000	0	0	0.0
vpm2	3.0	232	3.5	*1.122*	264	*1.096*	0	0	0.0	4.6	*1.400*	285	*1.160*	0	5	15.0
	3.0	330	3.0	1.003	257	**0.830**	0	4	20.0	2.9	0.992	316	0.967	0	0	20.0
	2.4	141	2.1	**0.901**	230	*1.369*	0	0	0.0	2.1	**0.915**	98	**0.822**	0	0	0.0
	2.9	256	3.1	*1.062*	233	**0.935**	0	9	17.0	3.5	*1.157*	206	**0.860**	0	0	24.0
vpphard	limit	1242	limit	1.000	1502	*1.194*	0	3	579.5	limit	1.000	3177	*2.442*	3	3868	145.0
	limit	3319	limit	1.000	2191	**0.670**	0	7	597.6	limit	1.000	3042	**0.919**	0	2005	220.4
	limit	3061	limit	1.000	2756	**0.904**	0	0	570.2	limit	1.000	3833	*1.244*	0	1843	174.3

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Table D.2: Computational results on MMMC: Conflict Diving

	nolockdiving		coefdiving						confdiving						
Instance	T	N	T	T_Q	N	N_Q	F	C	$D_\emptyset$	T	T_Q	N	N_Q	F	C	$D_\emptyset$
	limit	5091	limit	1.000	4061	**0.802**	0	8	611.0	limit	1.000	3090	**0.615**	0	1759	140.7
zib54-UUE	1758.3	73640	2091.8	*1.190*	76321	1.036	0	7	39.2	1538.5	**0.875**	63958	**0.869**	0	20	36.1
	1669.6	54829	1470.9	**0.881**	46323	**0.845**	0	12	35.0	2142.4	*1.283*	78209	*1.426*	0	23	32.9
	2375.8	79882	2338.4	0.984	74518	**0.933**	0	24	29.3	2181.3	**0.918**	60072	**0.752**	0	23	31.0
	2579.9	106384	1983.6	**0.769**	88765	**0.835**	1	33	33.0	1398.2	**0.542**	53450	**0.503**	1	26	39.3

Appendix E

Conflict Analysis for MINLP

- Table E.1 illustrates the impact of conflict analysis and dual proof analysis on general MINLPs as discussed in Section 7.3 compared to SCIP using an LP-based branch-and-bound without LP-based infeasibility analysis (`nolpinf`), applying conflict graph analysis to infeasible LPs (`confgraph`), and applying both conflict graph and dual proof analysis to infeasible LPs (`combined`).
- Table E.2 illustrates the impact of local dual proofs (`combined-local`) as described in Section 7.3 compared to SCIP without LP-based infeasibility analysis (`nolpinf`) and applying both conflict graph and dual proof analysis to infeasible LPs (`combined`).
- Table E.3 illustrates the impact of nonlinear dual proofs (`nlpinf`) as described in Section 7.4 within SCIP using an NLP-based branch-and-bound algorithm to SCIP without conflict analysis at all (`noconflict`) and only applying conflict graph analysis (`nonlpinf`).

Table E.1: Detailed computational results on MinlpLib. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
4stufen	∞	26	∞	1.000	26	1.000	∞	1.000	26	1.000
	∞	27	∞	1.000	27	1.000	∞	1.000	27	1.000
	33.02%	1351887	31.82%	1.000	1536609	1.137	30.43%	1.000	1466966	1.085
alan	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
autocorr_bern20-03	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
autocorr_bern20-05	52.77	36163	51.47	0.976	35340	0.977	50.17	0.952	33679	**0.932**
	53.02	36163	51.61	0.974	35340	0.977	50.31	**0.950**	33679	**0.932**
	52.73	36163	51.32	0.974	35340	0.977	49.84	**0.946**	33679	**0.932**
autocorr_bern20-10	491.69	169917	498.15	1.013	174456	1.027	488.03	0.993	170120	1.001
	495.49	173068	487.41	0.984	171548	0.991	494.40	0.998	171171	0.989
	501.46	184617	507.12	1.011	188015	1.018	498.15	0.993	172255	**0.933**
autocorr_bern20-15	949.24	168894	931.45	0.981	167760	0.993	996.70	1.050	169986	1.006
	945.28	168894	933.28	0.987	167760	0.993	991.63	1.049	169986	1.006
	943.81	168894	933.53	0.989	167760	0.993	988.21	1.047	169986	1.006
autocorr_bern25-03	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
autocorr_bern25-06	1151.54	1060923	1269.64	*1.102*	1133445	*1.068*	1070.98	**0.930**	956501	**0.902**
	1053.56	932298	1139.83	*1.082*	1022168	*1.096*	1141.22	*1.083*	1060245	*1.137*
	1219.57	1077557	1135.78	**0.931**	973892	**0.904**	1172.95	0.962	1039728	0.965
autocorr_bern25-13	97.55%	1064153	97.65%	1.000	1062455	0.998	97.55%	1.000	1064092	1.000
	97.96%	1057004	97.69%	1.000	1061768	1.005	97.60%	1.000	1063055	1.006
	98.03%	1056399	97.59%	1.000	1063075	1.006	97.78%	1.000	1060282	1.004
autocorr_bern25-19	134.87%	562861	134.74%	1.000	558643	0.993	152.64%	1.000	450391	0.800
	135.12%	560870	134.73%	1.000	558996	0.997	151.93%	1.000	454617	0.811
	134.79%	563583	134.00%	1.000	564464	1.002	152.54%	1.000	450832	0.800
autocorr_bern25-25	342.02%	328682	341.40%	1.000	327941	0.998	353.77%	1.000	289911	0.882
	373.18%	286811	372.75%	1.000	288576	1.006	389.32%	1.000	247944	0.865
	350.53%	322253	349.38%	1.000	322782	1.002	409.03%	1.000	204955	0.636

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
autocorr_bern30-04	463.70	668272	476.86	1.028	720283	*1.078*	567.49	*1.223*	824450	*1.234*
	477.45	702459	655.44	*1.372*	1018943	*1.450*	526.68	*1.103*	753958	*1.073*
	547.95	805399	760.18	*1.387*	1185016	*1.471*	600.81	*1.096*	891728	*1.107*
autocorr_bern30-08	202.04%	1448144	201.90%	1.000	1487584	1.027	202.73%	1.000	1472244	1.017
	207.67%	1516624	208.69%	1.000	1299003	0.857	198.10%	1.000	1426595	0.941
	205.87%	1513474	213.36%	1.000	1336015	0.883	213.66%	1.000	1335590	0.882
autocorr_bern30-15	229.66%	509542	229.13%	1.000	533604	1.047	227.94%	1.000	555814	1.091
	229.26%	513359	228.13%	1.000	535192	1.043	228.32%	1.000	552437	1.076
	229.80%	508534	228.11%	1.000	535397	1.053	228.01%	1.000	555074	1.091
autocorr_bern30-23	508.08%	88265	509.86%	1.000	89694	1.016	565.12%	1.000	63291	0.717
	506.76%	88982	510.86%	1.000	89352	1.004	565.45%	1.000	63197	0.711
	507.99%	88352	512.55%	1.000	87971	0.996	565.57%	1.000	63054	0.714
autocorr_bern30-30	1483.85%	66	1483.85%	1.000	66	1.000	1483.85%	1.000	66	1.000
	1483.85%	66	1483.85%	1.000	66	1.000	1483.85%	1.000	66	1.000
	1483.85%	66	1483.85%	1.000	66	1.000	1483.85%	1.000	66	1.000
autocorr_bern35-04	2692.43	3871001	3835.78	*1.424*	4883919	*1.262*	3979.89	*1.478*	5243100	*1.354*
	5636.04	7464527	4068.84	**0.722**	5660023	**0.758**	4934.99	**0.876**	5548734	**0.743**
	2700.58	3575852	2683.20	0.994	3654847	1.022	2619.70	0.970	3599710	1.007
autocorr_bern35-09	487.91%	590796	488.14%	1.000	589314	0.997	483.63%	1.000	624181	1.056
	426.06%	635177	420.34%	1.000	697786	1.099	427.86%	1.000	619435	0.975
	463.86%	665317	427.24%	1.000	650533	0.978	422.10%	1.000	729013	1.096
autocorr_bern35-18	464.77%	18161	462.98%	1.000	17595	0.969	464.43%	1.000	17601	0.969
	463.75%	18403	462.98%	1.000	17591	0.956	463.74%	1.000	17783	0.966
	464.65%	18190	463.55%	1.000	17432	0.959	464.25%	1.000	17644	0.970
autocorr_bern35-26	796.04%	26912	806.06%	1.000	25165	0.935	823.89%	1.000	18462	0.687
	796.11%	26779	806.74%	1.000	24971	0.933	823.89%	1.000	18451	0.690
	796.06%	26791	806.44%	1.000	25022	0.934	824.13%	1.000	18377	0.687
autocorr_bern35-35	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
autocorr_bern35-35fix	1051.92%	13522	1046.86%	1.000	13642	1.009	1059.01%	1.000	13402	0.991
	1052.42%	13265	1046.86%	1.000	13643	1.028	1057.80%	1.000	13481	1.016
	1052.19%	13431	1046.95%	1.000	13615	1.014	1057.91%	1.000	13462	1.002
autocorr_bern40-05	228.25%	1217445	226.97%	1.000	1158125	0.951	227.12%	1.000	1153835	0.948

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	226.52%	1207655	234.72%	1.000	1186815	0.983	234.75%	1.000	1186565	0.983
	226.79%	1184934	226.47%	1.000	1190165	1.004	226.36%	1.000	1204905	1.017
autocorr_bern40-10	689.08%	212755	688.22%	1.000	219963	1.034	700.37%	1.000	193733	0.911
	689.31%	212266	688.40%	1.000	219212	1.033	700.14%	1.000	194345	0.916
	689.19%	212642	688.38%	1.000	219391	1.032	700.14%	1.000	194345	0.914
autocorr_bern40-20	771.48%	32585	767.46%	1.000	33295	1.022	774.73%	1.000	31144	0.956
	771.18%	32731	768.44%	1.000	32891	1.005	773.96%	1.000	31353	0.958
	771.31%	32693	767.63%	1.000	33111	1.013	774.37%	1.000	31314	0.958
autocorr_bern40-30	1075.80%	10114	1069.44%	1.000	10291	1.017	1439.39%	1.000	1671	0.173
	1075.75%	10142	1070.00%	1.000	10229	1.008	1439.39%	1.000	1671	0.173
	1074.33%	10181	1070.00%	1.000	10221	1.004	1439.39%	1.000	1671	0.172
autocorr_bern45-05	284.44%	962976	273.22%	1.000	991065	1.029	266.25%	1.000	1045496	1.086
	255.13%	821226	248.84%	1.000	799636	0.974	248.58%	1.000	818156	0.996
	229.91%	855693	241.52%	1.000	841706	0.984	241.67%	1.000	837766	0.979
autocorr_bern45-11	974.61%	53532	974.81%	1.000	52876	0.988	973.52%	1.000	53331	0.996
	974.80%	53530	975.42%	1.000	52463	0.980	974.89%	1.000	52731	0.985
	979.05%	50751	977.14%	1.000	51836	1.021	975.97%	1.000	52292	1.030
autocorr_bern45-23	1461.68%	230	1461.68%	1.000	230	1.000	1461.68%	1.000	230	1.000
	1461.68%	230	1461.68%	1.000	230	1.000	1461.68%	1.000	230	1.000
	1461.68%	230	1461.68%	1.000	230	1.000	1461.68%	1.000	230	1.000
autocorr_bern50-06	555.48%	618825	558.98%	1.000	618926	1.000	559.16%	1.000	615996	0.995
	563.34%	670193	572.13%	1.000	619221	0.924	572.10%	1.000	619656	0.925
	564.49%	593334	560.25%	1.000	625896	1.055	561.97%	1.000	623547	1.051
autocorr_bern50-13	1504.10%	27	1504.10%	1.000	27	1.000	1504.10%	1.000	27	1.000
	1504.10%	27	1504.10%	1.000	27	1.000	1504.10%	1.000	27	1.000
	1504.10%	27	1504.10%	1.000	27	1.000	1504.10%	1.000	27	1.000
autocorr_bern50-25	1195.49%	1366	1164.26%	1.000	1704	1.231	1190.01%	1.000	1667	1.205
	1200.05%	1356	1164.26%	1.000	1711	1.244	1188.33%	1.000	1684	1.225
	1195.49%	1364	1164.26%	1.000	1711	1.237	1190.01%	1.000	1680	1.216
autocorr_bern50-50	1589.91%	627	1589.91%	1.000	624	0.996	1589.91%	1.000	623	0.994
	1589.91%	625	1589.91%	1.000	622	0.996	1589.91%	1.000	627	1.003
	1589.91%	627	1589.91%	1.000	628	1.001	1589.91%	1.000	624	0.996
autocorr_bern55-06	614.67%	422642	617.45%	1.000	410443	0.971	617.36%	1.000	411382	0.973
	637.26%	487076	638.78%	1.000	481804	0.989	638.97%	1.000	480353	0.986

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	665.01%	472967	665.89%	1.000	416782	0.881	665.56%	1.000	419246	0.886
autocorr_bern55-14	1615.30%	19	1615.30%	1.000	19	1.000	1615.30%	1.000	19	1.000
	1615.30%	19	1615.30%	1.000	19	1.000	1615.30%	1.000	19	1.000
	1615.30%	19	1615.30%	1.000	19	1.000	1615.30%	1.000	19	1.000
autocorr_bern55-28	1961.67%	25	1961.67%	1.000	25	1.000	1961.67%	1.000	25	1.000
	1961.67%	25	1961.67%	1.000	25	1.000	1961.67%	1.000	25	1.000
	1961.67%	25	1961.67%	1.000	25	1.000	1961.67%	1.000	25	1.000
autocorr_bern55-41	1719.76%	485	1697.34%	1.000	471	0.976	1719.76%	1.000	474	0.981
	1719.76%	484	1719.76%	1.000	453	0.947	1719.76%	1.000	455	0.950
autocorr_bern60-08	1003.02%	95554	1001.09%	1.000	97875	1.024	1000.88%	1.000	98005	1.026
	999.92%	99036	999.80%	1.000	99206	1.002	999.92%	1.000	99035	1.000
	1000.65%	98364	1000.87%	1.000	98026	0.997	1000.22%	1.000	98802	1.004
autocorr_bern60-15	1608.28%	25	1608.28%	1.000	25	1.000	1608.28%	1.000	25	1.000
	1608.28%	25	1608.28%	1.000	25	1.000	1608.28%	1.000	25	1.000
	1608.28%	25	1608.28%	1.000	25	1.000	1608.28%	1.000	25	1.000
autocorr_bern60-45	1821.82%	20	1821.82%	1.000	20	1.000	1821.82%	1.000	20	1.000
	1821.82%	20	1821.82%	1.000	20	1.000	1821.82%	1.000	20	1.000
	1821.82%	20	1821.82%	1.000	20	1.000	1821.82%	1.000	20	1.000
autocorr_bern60-60	$\geq$ 10000%	8	$\geq$ 10000%	1.000	8	1.000	$\geq$ 10000%	1.000	9	1.009
	$\geq$ 10000%	8	$\geq$ 10000%	1.000	8	1.000	$\geq$ 10000%	1.000	8	1.000
	$\geq$ 10000%	8	$\geq$ 10000%	1.000	8	1.000	$\geq$ 10000%	1.000	9	1.009
ball_mk2_10	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ball_mk2_30	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ball_mk3_10	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
ball_mk3_20	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ball_mk3_30	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ball_mk4_05	0.96	1913	1.00	1.020	1961	1.024	0.86	**0.949**	1007	**0.550**
	0.96	1913	1.01	1.026	1961	1.024	0.85	**0.944**	1007	**0.550**
	0.92	1913	0.96	1.021	1961	1.024	0.85	0.964	1007	**0.550**
ball_mk4_10	1170.38	2099707	1172.44	1.002	2110941	1.005	576.78	**0.493**	1177625	**0.561**
	1171.00	2099707	1172.66	1.001	2110941	1.005	577.94	**0.494**	1177625	**0.561**
	1169.01	2099707	1171.07	1.002	2110941	1.005	574.79	**0.492**	1177625	**0.561**
ball_mk4_15	∞	3175514	∞	1.000	3354229	1.056	∞	1.000	3459469	1.089
	∞	3107824	∞	1.000	3384352	1.089	∞	1.000	3466224	1.115
	∞	3145049	∞	1.000	3349481	1.065	∞	1.000	3440102	1.094
batch0812	0.78	3	0.83	1.028	3	1.000	0.78	1.000	3	1.000
	1.29	3	1.31	1.009	3	1.000	1.27	0.991	3	1.000
	0.74	3	0.75	1.006	3	1.000	0.75	1.006	3	1.000
batch0812_nc	3.64	262	3.64	1.000	262	1.000	3.68	1.009	262	1.000
	2.89	4	2.98	1.023	4	1.000	2.92	1.008	4	1.000
batch	1.06	2	1.09	1.015	2	1.000	1.11	1.024	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.76	2	0.78	1.011	2	1.000	0.76	1.000	2	1.000
batch_nc	2.41	181	2.37	0.988	181	1.000	2.38	0.991	181	1.000
	1.98	162	1.98	1.000	162	1.000	2.01	1.010	162	1.000
	3.26	281	3.30	1.009	281	1.000	3.24	0.995	281	1.000
batchdes	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
batchs101006m	8.35	521	9.43	*1.116*	486	**0.944**	5.05	**0.647**	101	**0.324**
	7.50	234	7.61	1.013	196	**0.886**	6.33	**0.862**	199	**0.895**
	9.93	522	7.49	**0.777**	356	**0.733**	6.97	**0.729**	190	**0.466**
batchs121208m	21.61	533	17.59	**0.822**	673	*1.221*	15.61	**0.735**	78	**0.281**
	14.60	122	20.61	*1.385*	623	*3.257*	18.80	*1.269*	443	*2.446*
	17.75	450	21.91	*1.222*	936	*1.884*	13.74	**0.786**	293	**0.715**
batchs151208m	17.00	1263	18.94	*1.108*	1609	*1.254*	17.44	1.024	1245	0.987
	13.24	552	10.77	**0.827**	298	**0.610**	10.10	**0.779**	281	**0.584**
	23.84	1581	33.93	*1.406*	1780	*1.118*	17.98	**0.764**	904	**0.597**

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
batchs201210m	20.64	879	19.50	**0.947**	918	1.040	19.21	**0.934**	779	**0.898**
	37.00	3794	32.50	**0.882**	3680	0.971	25.40	**0.695**	2299	**0.616**
	10.11	186	9.44	**0.940**	171	**0.948**	9.38	**0.934**	193	1.024
bchoco05	5.05%	2695165	5.05%	1.000	2666705	0.989	5.15%	1.000	2836035	1.052
	5.14%	1654056	5.14%	1.000	1647706	0.996	5.15%	1.000	2985583	1.805
	5.15%	4041334	5.15%	1.000	4017467	0.994	5.15%	1.000	5862141	1.451
bchoco06	4.46%	3408722	4.46%	1.000	3045119	0.893	4.46%	1.000	3338983	0.980
	3.86%	3015452	3.86%	1.000	4008454	1.329	3.86%	1.000	3293641	1.092
	∞	2523974	∞	1.000	2470903	0.979	∞	1.000	301178	0.119
bchoco07	∞	43	∞	1.000	43	1.000	∞	1.000	43	1.000
	4.45%	2691588	4.45%	1.000	2627859	0.976	4.45%	1.000	2693474	1.001
	∞	146	∞	1.000	146	1.000	∞	1.000	146	1.000
bchoco08	1.02	3	1.04	1.010	3	1.000	1.03	1.005	3	1.000
	∞	32891	∞	1.000	32891	1.000	∞	1.000	32891	1.000
	∞	13895	∞	1.000	13895	1.000	∞	1.000	13895	1.000
beuster	1340.95%	41818	1340.95%	1.000	41818	1.000	1340.95%	1.000	41818	1.000
	∞	6306	∞	1.000	6306	1.000	∞	1.000	6306	1.000
	∞	7533	∞	1.000	7533	1.000	∞	1.000	7533	1.000
blend029	4.55	3317	4.59	1.007	3317	1.000	4.57	1.004	3317	1.000
	9.47	6202	8.61	**0.918**	6554	*1.056*	8.58	**0.915**	6554	*1.056*
	4.81	2509	4.87	1.010	2451	0.978	4.92	1.019	2451	0.978
blend146	4657.71	4865371	5080.56	*1.091*	5306513	*1.091*	5148.42	*1.105*	5350331	*1.100*
	0.75%	6597090	0.55%	1.000	6805328	1.032	0.56%	1.000	7675348	1.163
blend480	1825.90	1012886	1049.13	**0.575**	664662	**0.656**	4354.80	*2.384*	3166931	*3.126*
	3037.21	2680281	3227.37	*1.063*	2729251	1.018	797.18	**0.263**	437674	**0.163**
blend531	169.38	112266	158.58	**0.937**	92577	**0.825**	122.12	**0.723**	67256	**0.599**
	141.74	74833	88.39	**0.626**	43773	**0.585**	39.18	**0.281**	12025	**0.162**
blend718	39.11%	5415586	7100.61	0.986	5013683	**0.926**	35.43%	1.000	5474564	1.011
	4214.01	3800829	2766.70	**0.657**	2621385	**0.690**	3557.27	**0.844**	3178101	**0.836**
	3303.28	2831792	2721.12	**0.824**	2582035	**0.912**	3461.61	1.048	3239623	*1.144*
blend721	57.03	25713	48.64	**0.855**	20490	**0.798**	51.39	**0.903**	21735	**0.846**
	21.20	8080	42.14	*1.943*	19440	*2.389*	40.72	*1.879*	18388	*2.260*
	44.31	23380	40.57	**0.917**	19425	**0.832**	40.83	**0.923**	19425	**0.832**

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Table E.1: Detailed computational results on MINLPLIB.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
cardqp_inlp	70.57%	190313	71.94%	1.000	191413	1.006	69.86%	1.000	190535	1.001
	70.37%	192107	71.70%	1.000	194237	1.011	69.88%	1.000	190289	0.991
	70.26%	192852	71.75%	1.000	193506	1.003	69.88%	1.000	190289	0.987
cardqp_iqp	70.40%	191847	71.77%	1.000	193371	1.008	70.03%	1.000	188835	0.984
	70.37%	192104	71.78%	1.000	193114	1.005	69.88%	1.000	190289	0.991
	70.35%	192334	71.72%	1.000	194003	1.009	69.98%	1.000	189296	0.984
carton7	322.77	349796	393.79	*1.219*	447163	*1.278*	353.03	*1.093*	383766	*1.097*
	395.54	404154	378.44	0.957	423548	1.048	736.67	*1.860*	632151	*1.564*
	356.86	400729	351.93	0.986	408737	1.020	310.52	**0.871**	344132	**0.859**
carton9	46.96%	3913948	72.58%	1.000	3556967	0.909	53.49%	1.000	1944616	0.497
	120.39%	3112599	82.31%	1.000	3944854	1.267	100.64%	1.000	3980588	1.279
	172.00%	2449627	184.96%	1.000	1722476	0.703	142.14%	1.000	2527996	1.032
casctanks	5327.30	269331	5248.35	0.985	269331	1.000	5315.31	0.998	269331	1.000
	302.20	30141	299.46	0.991	30141	1.000	301.65	0.998	30141	1.000
	0.34%	321823	0.23%	1.000	326869	1.016	0.34%	1.000	321596	0.999
case_1scv2	∞	76149	∞	1.000	36505	0.480	∞	1.000	52493	0.690
	∞	29097	∞	1.000	41583	1.428	∞	1.000	151047	5.177
	∞	30897	∞	1.000	37720	1.220	∞	1.000	47031	1.521
celar6-sub0	∞	480946	∞	1.000	500262	1.040	∞	1.000	496636	1.033
	∞	522985	∞	1.000	487903	0.933	∞	1.000	491885	0.941
	∞	517104	∞	1.000	509739	0.986	∞	1.000	476693	0.922
chp_partload	∞	71	∞	1.000	71	1.000	∞	1.000	71	1.000
	∞	97	∞	1.000	97	1.000	∞	1.000	110	1.066
	∞	100	∞	1.000	100	1.000	∞	1.000	100	1.000
chp_shorttermplan1a	15.12	26	15.20	1.005	26	1.000	15.07	0.997	24	0.984
	11.40	12	11.51	1.009	12	1.000	11.44	1.003	13	1.009
chp_shorttermplan1b	0.99%	502942	1.18%	1.000	483642	0.962	1.74%	1.000	294927	0.586
	0.68%	386715	0.59%	1.000	481294	1.245	0.87%	1.000	381611	0.987
	2.24%	324675	1.03%	1.000	327918	1.010	1.46%	1.000	260409	0.802
chp_shorttermplan2a	57.41	291	58.53	1.019	291	1.000	12.70	**0.235**	21	**0.309**
	142.89	2319	112.63	**0.790**	1994	**0.866**	155.24	*1.086*	2413	1.039
	114.76	190	85.98	**0.751**	190	1.000	96.78	**0.845**	1333	*4.941*
chp_shorttermplan2b	1.35%	133441	1.34%	1.000	134203	1.006	1.05%	1.000	176379	1.322
	0.80%	156100	0.86%	1.000	148359	0.950	0.75%	1.000	159768	1.023

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.77%	200907	0.82%	1.000	193613	0.964	1.15%	1.000	177585	0.884
chp_shorttermplan2c	∞	75073	∞	1.000	80091	1.067	∞	1.000	78212	1.042
	∞	76690	∞	1.000	80730	1.053	∞	1.000	78038	1.018
	∞	74930	∞	1.000	79480	1.061	∞	1.000	85829	1.145
chp_shorttermplan2d	3.33%	95265	3.80%	1.000	82388	0.865	3.17%	1.000	92093	0.967
	∞	108117	6.57%	1.000	85098	0.787	∞	1.000	113896	1.053
	4.63%	144371	6.41%	1.000	91523	0.634	3.93%	1.000	125254	0.868
clay0203h	5.37	441	5.38	1.002	441	1.000	5.42	1.008	441	1.000
	4.67	1151	4.66	0.998	1151	1.000	4.74	1.012	1151	1.000
	5.34	138	5.26	0.987	138	1.000	5.33	0.998	138	1.000
clay0203m	0.99	26	0.99	1.000	26	1.000	0.99	1.000	26	1.000
	0.94	59	0.93	0.995	55	0.975	0.93	0.995	55	0.975
	0.77	55	0.75	0.989	55	1.000	0.76	0.994	55	1.000
clay0204h	14.11	1012	13.92	0.987	917	**0.915**	13.83	0.981	976	0.968
	16.45	1235	17.33	*1.050*	1670	*1.326*	15.47	**0.944**	973	**0.804**
	16.16	1155	15.49	0.961	1099	0.955	16.64	1.028	1216	1.049
clay0204m	1.70	550	1.83	1.048	497	**0.918**	1.80	1.037	515	**0.946**
	1.94	467	1.99	1.017	510	*1.076*	1.90	0.986	510	*1.076*
	1.57	509	1.30	**0.895**	480	0.952	1.31	**0.899**	480	0.952
clay0205h	135.58	10890	146.77	*1.082*	44506	*4.059*	120.56	**0.890**	17590	*1.610*
	86.91	8022	88.96	1.023	8229	1.025	77.05	**0.888**	7722	0.963
	100.66	10307	99.99	0.993	11164	*1.082*	131.44	*1.303*	15162	*1.467*
clay0205m	4.58	2749	5.09	*1.091*	3061	*1.110*	5.13	*1.099*	3042	*1.103*
	6.54	2864	7.22	*1.090*	3471	*1.205*	6.88	1.045	3531	*1.225*
	5.59	3163	5.77	1.027	3776	*1.188*	6.12	*1.080*	3882	*1.220*
clay0303h	4.15	214	4.12	0.994	214	1.000	4.16	1.002	214	1.000
	6.63	451	6.63	1.000	451	1.000	6.60	0.996	451	1.000
	7.44	435	7.42	0.998	435	1.000	7.45	1.001	435	1.000
clay0303m	1.62	15	1.63	1.004	15	1.000	1.62	1.000	15	1.000
	1.67	61	1.66	0.996	61	1.000	1.66	0.996	61	1.000
	2.32	163	2.38	1.018	163	1.000	2.36	1.012	163	1.000
clay0304m	2.42	318	2.44	1.006	240	**0.813**	2.52	1.029	257	**0.854**
	1.91	339	1.75	**0.945**	287	**0.882**	1.70	**0.928**	267	**0.836**
	2.12	170	2.12	1.000	169	0.996	2.05	0.978	169	0.996

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
clay0305h	163.22	14047	172.70	*1.058*	15716	*1.118*	161.46	0.989	13482	0.960
	118.96	12057	146.78	*1.232*	15074	*1.248*	103.11	**0.868**	10537	**0.875**
	119.89	11979	120.25	1.003	11768	0.983	115.44	0.963	11750	0.981
clay0305m	6.12	3711	6.03	0.987	3942	*1.061*	6.59	*1.066*	4748	*1.272*
	8.39	3708	8.50	1.012	4202	*1.130*	8.21	0.981	3676	0.992
	8.06	2748	7.60	**0.949**	2757	1.003	7.74	0.965	2857	1.038
color_lab2_4x0	7641.40%	309082	≥ 10000%	1.000	240042	0.777	≥ 10000%	1.000	215224	0.696
	2045.62%	197211	2993.84%	1.000	198878	1.008	2413.76%	1.000	225845	1.145
	1797.58%	214899	1819.00%	1.000	230549	1.073	1681.59%	1.000	322658	1.501
color_lab3_3x0	92.35%	2010699	96.95%	1.000	1725799	0.858	96.99%	1.000	1720449	0.856
	91.15%	1884899	85.45%	1.000	1101190	0.584	85.49%	1.000	1098706	0.583
	90.42%	1826299	91.98%	1.000	1649702	0.903	92.01%	1.000	1645599	0.901
color_lab3_4x0	234.55%	323970	304.15%	1.000	1185993	3.660	304.36%	1.000	1175073	3.626
	229.66%	394330	238.09%	1.000	330092	0.837	238.11%	1.000	329820	0.836
	235.69%	361819	226.19%	1.000	370660	1.024	226.11%	1.000	371790	1.028
color_lab6b_4x20	∞	86085	∞	1.000	113330	1.316	∞	1.000	74448	0.865
	∞	37281	∞	1.000	43527	1.167	∞	1.000	44385	1.190
	∞	32493	∞	1.000	31986	0.984	∞	1.000	41997	1.292
contvar	105.93%	96724	105.93%	1.000	95825	0.991	106.62%	1.000	86566	0.895
	∞	69	∞	1.000	69	1.000	∞	1.000	69	1.000
	∞	22	∞	1.000	22	1.000	∞	1.000	22	1.000
crossdock_15x7	∞	43032	∞	1.000	47413	1.102	∞	1.000	46061	1.070
	∞	38593	∞	1.000	34821	0.903	∞	1.000	33309	0.863
	∞	40919	∞	1.000	43507	1.063	∞	1.000	42634	1.042
crossdock_15x8	∞	46540	∞	1.000	34456	0.741	∞	1.000	32094	0.690
	∞	38630	∞	1.000	38845	1.006	∞	1.000	35486	0.919
	∞	42033	∞	1.000	33339	0.794	∞	1.000	31070	0.740
crudeoil_lee1_05	1.65	5	1.63	0.992	5	1.000	1.64	0.996	5	1.000
	1.51	3	1.50	0.996	3	1.000	1.57	1.024	3	1.000
	2.65	8	2.63	0.995	8	1.000	2.57	0.978	8	1.000
crudeoil_lee1_06	1.67	52	1.69	1.007	54	1.013	1.61	0.978	50	0.987
	2.34	92	2.31	0.991	102	*1.052*	2.31	0.991	79	**0.932**
	2.25	38	2.22	0.991	38	1.000	2.26	1.003	38	1.000
crudeoil_lee1_07	4.32	20	4.13	0.964	24	1.033	4.17	0.972	20	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	5.36	30	5.04	**0.950**	22	**0.938**	5.34	0.997	30	1.000
	2.71	82	2.71	1.000	75	0.962	2.66	0.987	76	0.967
crudeoil_lee1_08	4.53	97	4.58	1.009	88	0.954	4.49	0.993	89	0.959
	5.83	148	6.98	*1.168*	223	*1.302*	4.88	**0.861**	120	**0.887**
	4.59	71	4.51	0.986	73	1.012	4.44	0.973	71	1.000
crudeoil_lee1_09	8.51	102	7.26	**0.869**	116	*1.069*	7.16	**0.858**	112	1.050
	9.98	153	8.88	**0.900**	120	**0.870**	9.33	**0.941**	141	0.953
	9.94	153	10.33	1.036	175	*1.087*	10.08	1.013	105	**0.810**
crudeoil_lee1_10	8.01	187	7.74	0.970	171	**0.944**	7.96	0.994	187	1.000
	11.94	178	11.00	**0.927**	99	**0.716**	11.42	0.960	125	**0.809**
crudeoil_lee2_05	10.41	74	10.09	0.972	74	1.000	10.02	0.966	74	1.000
	15.08	5	14.98	0.994	5	1.000	15.03	0.997	5	1.000
	17.98	20	17.50	0.975	20	1.000	17.61	0.981	20	1.000
crudeoil_lee2_06	7.91	142	7.53	0.957	103	**0.839**	7.89	0.998	123	**0.921**
	18.80	311	17.35	**0.927**	125	**0.547**	17.54	**0.936**	169	**0.655**
	20.97	161	19.57	**0.936**	18	**0.452**	19.75	**0.944**	21	**0.464**
crudeoil_lee2_07	26.62	423	25.08	**0.944**	344	**0.849**	26.53	0.997	270	**0.707**
	29.27	275	27.42	**0.939**	217	**0.845**	28.51	0.975	223	**0.861**
	31.28	403	29.73	0.952	254	**0.704**	29.16	**0.934**	308	**0.811**
crudeoil_lee2_08	41.08	464	45.37	*1.102*	591	*1.225*	39.82	0.970	293	**0.697**
	45.62	683	45.78	1.003	471	**0.729**	45.12	0.989	607	**0.903**
crudeoil_lee2_09	38.86	479	33.86	**0.875**	320	**0.725**	33.93	**0.876**	242	**0.591**
	34.77	631	31.63	**0.912**	519	**0.847**	35.92	1.032	553	**0.893**
	57.44	835	47.79	**0.835**	474	**0.614**	43.04	**0.754**	259	**0.384**
crudeoil_lee2_10	73.88	520	75.21	1.018	621	*1.163*	88.08	*1.190*	979	*1.740*
	69.09	409	66.02	0.956	551	*1.279*	64.43	**0.934**	415	1.012
	88.97	366	88.39	0.994	349	0.964	88.68	0.997	328	**0.918**
crudeoil_lee3_05	15.73	821	17.44	*1.102*	1561	*1.803*	16.69	*1.057*	1351	*1.575*
	26.68	1472	21.70	**0.820**	852	**0.606**	25.97	0.974	1972	*1.318*
	18.51	2811	13.70	**0.753**	1531	**0.560**	11.26	**0.628**	1161	**0.433**
crudeoil_lee3_06	56.66	7232	60.06	*1.059*	9122	*1.258*	53.12	**0.939**	4152	**0.580**
	58.37	15001	50.69	**0.871**	10761	**0.719**	50.45	**0.867**	10831	**0.724**
crudeoil_lee3_07	111.59	24111	87.02	**0.782**	11191	**0.466**	124.45	*1.114*	30391	*1.259*
	49.47	7181	52.89	*1.068*	8431	*1.172*	51.22	1.035	8121	*1.129*

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	83.15	15861	0.31%	85.573	3234423	202.652	63.36	**0.765**	8831	**0.560**
crudeoil_lee3_08	121.99	25921	83.48	**0.687**	15401	**0.596**	87.80	**0.722**	13431	**0.520**
	95.02	12911	130.28	*1.367*	33841	*2.609*	82.92	**0.874**	13541	1.048
	112.93	19883	111.44	0.987	16331	**0.822**	122.24	*1.082*	20381	1.025
crudeoil_lee3_09	350.13	64951	176.53	**0.506**	21651	**0.334**	198.00	**0.567**	29561	**0.456**
	138.45	17821	129.74	**0.938**	21592	*1.210*	169.62	*1.224*	32861	*1.839*
	233.05	42631	234.77	1.007	45211	*1.060*	123.37	**0.531**	9181	**0.217**
crudeoil_lee3_10	212.39	33391	157.03	**0.741**	21573	**0.647**	155.86	**0.735**	19631	**0.589**
	259.28	31761	220.06	**0.849**	23761	**0.749**	264.88	1.022	37431	*1.178*
crudeoil_lee4_05	24.60	119	24.61	1.000	118	0.995	24.83	1.009	82	**0.831**
	11.85	52	11.82	0.998	53	1.007	11.70	0.988	88	*1.237*
	10.14	57	9.86	0.975	57	1.000	9.86	0.975	57	1.000
crudeoil_lee4_06	16.40	17	16.24	0.991	17	1.000	17.27	*1.050*	18	1.009
	20.84	212	20.52	0.985	61	**0.516**	21.18	1.016	106	**0.660**
	16.42	12	15.86	0.968	12	1.000	16.20	0.987	9	0.973
crudeoil_lee4_07	44.61	326	43.52	0.976	136	**0.554**	46.09	1.032	56	**0.366**
	26.57	196	25.70	0.968	7	**0.361**	26.09	0.983	8	**0.365**
	27.01	14	26.80	0.993	13	0.991	26.86	0.995	13	0.991
crudeoil_lee4_08	35.15	220	34.87	0.992	399	*1.559*	40.41	*1.146*	306	*1.269*
	36.57	145	37.51	1.025	63	**0.665**	34.29	**0.939**	22	**0.498**
	49.14	86	42.75	**0.873**	28	**0.688**	43.06	**0.879**	27	**0.683**
crudeoil_lee4_09	42.33	145	38.44	**0.910**	30	**0.531**	40.45	0.957	29	**0.527**
	51.79	11	51.18	0.988	11	1.000	51.98	1.004	11	1.000
	69.86	279	72.09	1.031	128	**0.602**	71.95	1.029	139	**0.631**
crudeoil_lee4_10	62.72	162	58.64	**0.936**	23	**0.469**	57.86	**0.924**	58	**0.603**
	100.81	51	99.49	0.987	21	**0.801**	100.41	0.996	21	**0.801**
	69.64	18	66.99	0.962	10	**0.932**	69.57	0.999	18	1.000
crudeoil_li01	0.32%	3374015	0.44%	1.000	3317488	0.983	0.23%	1.000	3182383	0.943
	0.89%	2655335	0.39%	1.000	3134694	1.181	0.35%	1.000	2951935	1.112
	0.40%	3441744	0.39%	1.000	3526158	1.025	0.15%	1.000	3730750	1.084
crudeoil_li02	1.13%	3640454	1.14%	1.000	3703772	1.017	1.15%	1.000	3644347	1.001
	1.15%	3597634	1.13%	1.000	3703927	1.030	1.14%	1.000	3648778	1.014
	1.14%	3722327	1.22%	1.000	3301105	0.887	1.14%	1.000	3679411	0.988
crudeoil_li03	1.86%	1147729	1.72%	1.000	1154129	1.006	1.63%	1.000	921928	0.803

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	2.56%	932596	1.70%	1.000	890430	0.955	1.52%	1.000	963142	1.033
	2.31%	1254294	1.73%	1.000	1027649	0.819	1.85%	1.000	942504	0.751
crudeoil_li05	10.47%	1578334	9.45%	1.000	1298709	0.823	9.12%	1.000	1165963	0.739
	7.37%	1577838	9.12%	1.000	1172093	0.743	8.82%	1.000	1124347	0.713
	10.39%	1528726	8.89%	1.000	1286279	0.841	6.69%	1.000	1325981	0.867
	5190.54	713256	510.28	**0.098**	33495	**0.047**	340.72	**0.066**	25749	**0.036**
crudeoil_li11	1.52%	1328436	1.54%	1.000	720543	0.542	1.32%	1.000	890734	0.671
	1.21%	1068181	1.03%	1.000	929792	0.870	1.38%	1.000	931315	0.872
	1.56%	1214546	1.81%	1.000	781267	0.643	1.45%	1.000	784653	0.646
crudeoil_li21	2.21%	921212	1.33%	1.000	807512	0.877	1.27%	1.000	766632	0.832
	2.24%	912240	1.61%	1.000	585522	0.642	1.42%	1.000	672707	0.737
	2.11%	755525	1.68%	1.000	708493	0.938	1.69%	1.000	663031	0.878
crudeoil_pooling_ct1	36.19%	984573	31.65%	1.000	914249	0.929	32.19%	1.000	899549	0.914
	37.11%	936780	32.47%	1.000	938053	1.001	32.67%	1.000	855436	0.913
crudeoil_pooling_ct2	0.53%	6135205	0.50%	1.000	5968294	0.973	0.03%	1.000	4189108	0.683
	0.05%	4842949	0.02%	1.000	5318576	1.098	0.13%	1.000	3917810	0.809
	0.56%	7139400	0.04%	1.000	4648061	0.651	0.30%	1.000	4368439	0.612
crudeoil_pooling_ct3	41.39%	469185	37.15%	1.000	393282	0.838	39.84%	1.000	466466	0.994
	56.84%	375517	47.19%	1.000	425138	1.132	50.12%	1.000	398690	1.062
	48.09%	441303	37.29%	1.000	403038	0.913	45.58%	1.000	338915	0.768
crudeoil_pooling_ct4	2.34%	4770692	2.60%	1.000	4482170	0.940	2.37%	1.000	4684862	0.982
	2.31%	4350995	2.51%	1.000	4634230	1.065	2.44%	1.000	4514273	1.038
	3.10%	4573711	3.10%	1.000	4546039	0.994	3.14%	1.000	4218045	0.922
crudeoil_pooling_dt1	441.21	5342	515.94	*1.169*	5901	*1.103*	484.26	*1.097*	3991	**0.752**
	948.35	29047	1246.68	*1.314*	53506	*1.839*	1261.86	*1.330*	53506	*1.839*
	492.17	7998	452.95	**0.920**	5237	**0.659**	424.13	**0.862**	3655	**0.464**
crudeoil_pooling_dt2	7.38%	252679	6.72%	1.000	220994	0.875	7.92%	1.000	192393	0.762
	11.73%	160388	9.74%	1.000	198908	1.240	10.12%	1.000	225956	1.409
	10.72%	188043	6.43%	1.000	256816	1.366	8.03%	1.000	221634	1.179
crudeoil_pooling_dt3	4.43%	469413	5107.49	**0.709**	165811	**0.353**	1556.74	**0.216**	14717	**0.032**
	3960.90	137179	2086.02	**0.527**	24288	**0.178**	2081.53	**0.526**	24318	**0.178**
	2121.15	27711	2702.33	*1.274*	61179	*2.203*	3065.39	*1.445*	83541	*3.007*
crudeoil_pooling_dt4	8.11%	392086	8.15%	1.000	293094	0.748	8.10%	1.000	280858	0.716
	8.13%	207523	8.14%	1.000	250305	1.206	8.09%	1.000	244006	1.176

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	8.18%	253558	8.19%	1.000	216383	0.853	8.19%	1.000	256317	1.011
csched2	821.26%	571518	832.05%	1.000	192692	0.337	836.39%	1.000	114356	0.200
	839.69%	497	814.89%	1.000	282595	473.526	811.08%	1.000	988342	1655.682
cvxnonsep_normcon20	1.07	5	1.09	1.010	5	1.000	1.09	1.010	5	1.000
	1.10	5	1.08	0.990	5	1.000	1.10	1.000	5	1.000
	1.09	5	1.05	0.981	5	1.000	1.10	1.005	5	1.000
cvxnonsep_normcon20r	0.50	24	0.50	1.000	24	1.000	0.50	1.000	24	1.000
	0.50	24	0.50	1.000	24	1.000	0.50	1.000	24	1.000
	0.50	24	0.50	1.000	24	1.000	0.50	1.000	24	1.000
cvxnonsep_normcon30	4.49	354	4.77	*1.051*	340	0.969	4.74	1.046	376	1.048
	4.55	354	4.75	1.036	340	0.969	4.73	1.032	376	1.048
	4.57	354	4.70	1.023	340	0.969	4.82	1.045	376	1.048
cvxnonsep_normcon30r	0.59	49	0.61	1.013	56	1.047	0.61	1.013	56	1.047
	0.62	49	0.62	1.000	56	1.047	0.61	0.994	56	1.047
	0.57	49	0.58	1.006	56	1.047	0.62	1.032	56	1.047
cvxnonsep_normcon40	32.00	9564	30.70	0.961	9540	0.998	32.82	1.025	7675	**0.805**
	32.08	9564	30.90	0.964	9540	0.998	32.95	1.026	7675	**0.805**
	32.06	9564	30.80	0.962	9540	0.998	32.82	1.023	7675	**0.805**
cvxnonsep_normcon40r	0.69	57	0.73	1.024	81	*1.153*	0.75	1.036	79	*1.140*
	0.71	57	0.74	1.018	81	*1.153*	0.72	1.006	79	*1.140*
	0.70	57	0.74	1.024	81	*1.153*	0.78	1.047	79	*1.140*
cvxnonsep_nsig20	1.30%	755263	1.22%	1.000	828703	1.097	3.61%	1.000	42918	0.057
	1.28%	759792	1.23%	1.000	826935	1.088	3.61%	1.000	42918	0.057
	1.28%	760253	1.22%	1.000	829327	1.091	3.61%	1.000	42918	0.057
cvxnonsep_nsig20r	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
cvxnonsep_nsig30	6.15%	329471	5.13%	1.000	209334	0.635	5.68%	1.000	304528	0.924
	6.15%	327651	5.13%	1.000	209224	0.639	5.68%	1.000	304720	0.930
	6.15%	329372	5.13%	1.000	209224	0.635	5.68%	1.000	303019	0.920
cvxnonsep_nsig30r	0.50	41	0.50	1.000	41	1.000	0.50	1.000	51	*1.071*
	0.50	41	0.50	1.000	41	1.000	0.50	1.000	51	*1.071*
	0.50	41	0.50	1.000	41	1.000	0.50	1.000	51	*1.071*
cvxnonsep_nsig40	16.84%	228	16.84%	1.000	228	1.000	16.84%	1.000	228	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	16.84%	228	16.84%	1.000	228	1.000	16.84%	1.000	228	1.000
	16.84%	228	16.84%	1.000	228	1.000	16.84%	1.000	228	1.000
cvxnonsep_nsig40r	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
cvxnonsep_pcon20	0.50	48	0.50	1.000	48	1.000	0.50	1.000	48	1.000
	0.50	48	0.50	1.000	48	1.000	0.50	1.000	48	1.000
	0.50	48	0.50	1.000	48	1.000	0.50	1.000	48	1.000
cvxnonsep_pcon20r	0.50	26	0.50	1.000	26	1.000	0.50	1.000	26	1.000
	0.50	26	0.50	1.000	26	1.000	0.50	1.000	26	1.000
	0.50	26	0.50	1.000	26	1.000	0.50	1.000	26	1.000
cvxnonsep_pcon30	0.50	63	0.50	1.000	63	1.000	0.50	1.000	59	0.975
	0.50	63	0.50	1.000	63	1.000	0.50	1.000	59	0.975
	0.50	63	0.50	1.000	63	1.000	0.50	1.000	59	0.975
cvxnonsep_pcon30r	0.64	104	0.58	0.963	104	1.000	0.66	1.012	104	1.000
	0.82	132	0.82	1.000	132	1.000	0.70	**0.934**	137	1.022
cvxnonsep_pcon40	0.50	82	0.50	1.000	82	1.000	0.56	1.040	78	0.978
	0.50	82	0.53	1.020	82	1.000	0.53	1.020	78	0.978
	0.53	82	0.51	0.987	82	1.000	0.52	0.993	78	0.978
cvxnonsep_pcon40r	0.51	30	0.50	0.993	30	1.000	0.50	0.993	30	1.000
	0.84	178	0.86	1.011	177	0.996	0.87	1.016	177	0.996
	0.50	22	0.50	1.000	22	1.000	0.51	1.007	22	1.000
cvxnonsep_psig20	7.91	2311	7.45	**0.948**	2351	1.017	6.60	**0.853**	1426	**0.633**
	7.74	2311	7.59	0.983	2351	1.017	6.62	**0.872**	1426	**0.633**
	7.80	2311	7.33	**0.947**	2351	1.017	6.69	**0.874**	1426	**0.633**
cvxnonsep_psig20r	0.50	6	0.50	1.000	6	1.000	0.50	1.000	6	1.000
	0.50	6	0.50	1.000	6	1.000	0.50	1.000	6	1.000
	0.50	6	0.50	1.000	6	1.000	0.50	1.000	6	1.000
cvxnonsep_psig30	2.81%	851436	3.74%	1.000	451386	0.530	5.00%	1.000	373289	0.438
	2.81%	852728	3.74%	1.000	451386	0.529	5.00%	1.000	372455	0.437
	2.82%	847651	3.74%	1.000	450257	0.531	5.00%	1.000	372555	0.440
cvxnonsep_psig30r	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
cvxnonsep_psig40	3.80%	253151	3.47%	1.000	225959	0.893	3.07%	1.000	199854	0.790
	3.80%	252895	3.47%	1.000	226190	0.894	3.07%	1.000	199854	0.790
	3.79%	254153	3.47%	1.000	226930	0.893	3.07%	1.000	199433	0.785
cvxnonsep_psig40r	0.59	85	0.60	1.006	100	*1.081*	0.63	1.025	85	1.000
	0.59	85	0.57	0.987	100	*1.081*	0.63	1.025	85	1.000
	0.62	85	0.59	0.981	100	*1.081*	0.63	1.006	85	1.000
densitymod	∞	4310	∞	1.000	3405	0.795	∞	1.000	3400	0.794
	∞	4366	∞	1.000	4622	1.057	∞	1.000	4692	1.073
	∞	1833	∞	1.000	1185	0.665	∞	1.000	1055	0.598
du-opt5	0.53	54	0.51	0.987	54	1.000	0.55	1.013	61	1.045
	0.55	54	0.54	0.994	54	1.000	0.56	1.006	61	1.045
	0.57	54	0.54	0.981	54	1.000	0.52	0.968	61	1.045
du-opt	11.60	12715	10.92	**0.946**	12012	**0.945**	12.26	*1.052*	11697	**0.921**
	13.22	14279	13.36	1.010	14035	0.983	12.83	0.973	12519	**0.878**
	11.51	12715	11.13	0.970	12012	**0.945**	12.21	*1.056*	11697	**0.921**
edgecross10-010	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
edgecross10-020	1.20	270	1.53	*1.150*	313	*1.116*	1.63	*1.195*	337	*1.181*
	0.81	142	0.73	0.956	109	**0.864**	0.77	0.978	97	**0.814**
	1.14	135	1.13	0.995	138	1.013	1.22	1.037	93	**0.821**
edgecross10-030	1.99	775	1.96	0.990	650	**0.857**	1.99	1.000	650	**0.857**
	2.97	1097	2.60	**0.907**	1032	**0.946**	2.60	**0.907**	1032	**0.946**
	1.65	730	1.37	**0.894**	726	0.995	1.36	**0.891**	726	0.995
edgecross10-040	8.01	1956	6.66	**0.850**	1679	**0.865**	6.62	**0.846**	1640	**0.846**
	6.54	1681	6.07	**0.938**	1669	0.993	5.97	**0.924**	1631	0.972
	6.88	1749	6.49	0.951	1814	1.035	6.56	0.959	1814	1.035
edgecross10-050	16.94	3537	23.88	*1.387*	4418	*1.242*	23.44	*1.362*	4293	*1.208*
	25.69	4448	29.27	*1.134*	5237	*1.173*	30.24	*1.170*	5526	*1.237*
	56.95	17193	49.89	**0.878**	13111	**0.764**	49.02	**0.863**	13244	**0.772**
edgecross10-060	517.29	4769	521.32	1.008	4769	1.000	515.82	0.997	4769	1.000
	458.70	4881	458.82	1.000	4881	1.000	458.60	1.000	4881	1.000
	467.61	5019	466.86	0.998	5019	1.000	467.61	1.000	5019	1.000
edgecross10-070	236.82	127172	230.93	0.975	135707	*1.067*	238.13	1.006	141806	*1.115*

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1333.47	1236422	921.70	**0.691**	918057	**0.743**	1095.21	**0.821**	911483	**0.737**
	209.76	138184	162.65	**0.776**	95240	**0.689**	140.43	**0.671**	90311	**0.654**
edgecross10-080	148.07	13507	149.18	1.007	13614	1.008	149.80	1.012	13614	1.008
	204.81	17820	196.49	0.960	16415	**0.922**	201.72	0.985	17410	0.977
	188.61	16635	183.29	0.972	16103	0.968	186.42	0.988	14933	**0.898**
edgecross10-090	3.37	915	2.72	**0.851**	770	**0.857**	2.71	**0.849**	770	**0.857**
	1.43	488	1.35	0.967	418	**0.881**	1.37	0.975	418	**0.881**
	1.86	278	1.85	0.997	296	1.048	1.89	1.010	296	1.048
edgecross14-019	2.33	296	2.14	**0.943**	225	**0.821**	2.04	**0.913**	223	**0.816**
	1.16	129	1.23	1.032	92	**0.838**	1.24	1.037	90	**0.830**
	0.99	99	0.98	0.995	99	1.000	1.03	1.020	103	1.020
edgecross14-039	4341.15	4155	4376.16	1.008	4155	1.000	4335.88	0.999	4155	1.000
	1934.04	1944	1943.29	1.005	1944	1.000	1932.31	0.999	1944	1.000
	1590.19	1568	1597.86	1.005	1568	1.000	1610.02	1.012	1568	1.000
edgecross14-058	581.36	291958	595.58	1.024	282539	0.968	611.12	*1.051*	300039	1.028
	266.06	104794	338.50	*1.271*	111627	*1.065*	247.29	**0.930**	88497	**0.845**
	5808.54	4327580	1221.54	**0.210**	690311	**0.160**	1064.61	**0.183**	607145	**0.140**
edgecross14-078	24.27%	115521	24.93%	1.000	116040	1.004	25.53%	1.000	110534	0.957
	22.79%	124591	22.07%	1.000	126657	1.017	22.26%	1.000	126203	1.013
	22.96%	122887	24.73%	1.000	114045	0.928	24.41%	1.000	117076	0.953
edgecross14-098	20.59%	5329722	17.45%	1.000	5182625	0.972	17.90%	1.000	5060707	0.950
	25.82%	5087295	26.87%	1.000	4703751	0.925	26.64%	1.000	4716185	0.927
	36.09%	4287395	19.92%	1.000	4082296	0.952	19.62%	1.000	4642231	1.083
edgecross14-117	9.76%	5531429	10.79%	1.000	5179311	0.936	12.12%	1.000	4966488	0.898
	26.06%	3837290	17.08%	1.000	4703225	1.226	17.64%	1.000	4566615	1.190
	21.28%	4336493	18.24%	1.000	4520159	1.042	17.34%	1.000	4739834	1.093
edgecross14-137	9.99%	2782991	7.83%	1.000	2893338	1.040	7.51%	1.000	2863847	1.029
	6.41%	3193505	5968.57	**0.829**	2012254	**0.630**	5717.29	**0.794**	1992360	**0.624**
	7190.64	3144912	5.36%	1.001	3002553	0.955	5840.82	**0.812**	2630592	**0.836**
edgecross14-156	19.58%	13319	19.17%	1.000	10904	0.820	18.79%	1.000	18015	1.350
	19.80%	14546	19.41%	1.000	17733	1.218	20.48%	1.000	19122	1.312
	19.31%	13894	18.72%	1.000	14344	1.032	19.86%	1.000	18613	1.337
edgecross14-176	743.39	237754	585.92	**0.788**	207507	**0.873**	695.11	**0.935**	229531	0.965
	582.89	186746	635.41	*1.090*	198674	*1.064*	581.60	0.998	193451	1.036

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	667.10	213780	776.32	*1.163*	255344	*1.194*	689.95	1.034	241312	*1.129*
edgecross20-040	468.62	36563	587.88	*1.254*	36835	1.007	570.92	*1.218*	38435	*1.051*
	421.75	28481	436.79	1.036	26528	**0.932**	417.69	0.990	26781	**0.941**
	425.59	30283	424.00	0.996	29463	0.973	436.67	1.026	31330	1.034
edgecross20-080	139.66%	632342	156.33%	1.000	577911	0.914	135.19%	1.000	661824	1.047
	136.74%	517874	151.45%	1.000	675997	1.305	140.36%	1.000	603343	1.165
	177.59%	519766	152.24%	1.000	558791	1.075	150.65%	1.000	492198	0.947
edgecross22-048	3191.29	193582	2597.10	**0.814**	130458	**0.674**	2401.56	**0.753**	133871	**0.692**
	3983.46	279043	4590.45	*1.152*	249908	**0.896**	3866.43	0.971	238102	**0.853**
	2527.53	142483	2193.31	**0.868**	151084	*1.060*	2794.83	*1.106*	173577	*1.218*
edgecross22-096	306.42%	270582	304.00%	1.000	254192	0.939	268.80%	1.000	253141	0.936
	232.36%	241083	209.28%	1.000	265002	1.099	243.10%	1.000	258248	1.071
	393.75%	241073	284.79%	1.000	245271	1.017	224.48%	1.000	245555	1.019
edgecross24-057	187.88%	327021	162.55%	1.000	397634	1.216	132.04%	1.000	435863	1.333
	223.16%	274972	232.58%	1.000	309095	1.124	259.38%	1.000	279412	1.016
	252.59%	328704	211.63%	1.000	309571	0.942	239.21%	1.000	335724	1.021
edgecross24-115	748.63%	174152	694.38%	1.000	123969	0.712	692.91%	1.000	121231	0.696
	577.37%	159553	581.47%	1.000	121527	0.762	567.63%	1.000	120339	0.754
	530.93%	113497	513.44%	1.000	131567	1.159	524.43%	1.000	145198	1.279
eg_all_s	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
eg_disc2_s	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
eg_disc_s	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
eg_int_s	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
elf	0.91	278	0.88	0.984	256	**0.942**	0.89	0.990	256	**0.942**
	0.84	275	0.91	1.038	321	*1.123*	0.81	0.984	275	1.000
	0.50	275	0.50	1.000	298	*1.061*	0.50	1.000	194	**0.784**

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
eniplac	1.97	34	2.03	1.020	34	1.000	2.02	1.017	34	1.000
	3.84	3	3.85	1.002	3	1.000	3.81	0.994	3	1.000
	2.05	3	2.11	1.020	3	1.000	2.15	1.033	3	1.000
enpro48pb	2.83	9	2.83	1.000	13	1.037	2.98	1.039	13	1.037
	3.06	60	2.72	**0.916**	36	**0.850**	2.73	**0.919**	34	**0.838**
	2.57	88	2.08	**0.863**	33	**0.707**	2.07	**0.860**	37	**0.729**
enpro56pb	6.81	180	7.25	*1.056*	218	*1.136*	6.26	**0.930**	105	**0.732**
	5.82	166	5.80	0.997	124	**0.842**	5.75	0.990	164	0.992
	6.60	74	6.26	0.955	59	**0.914**	6.40	0.974	67	0.960
ethanolh	155.23%	1079145	155.45%	1.000	1066915	0.989	155.31%	1.000	1075823	0.997
	79.88%	1460444	79.95%	1.000	1455524	0.997	78.24%	1.000	1499001	1.026
	333.70%	821	333.70%	1.000	821	1.000	333.70%	1.000	821	1.000
ethanolm	33.75%	1505181	33.68%	1.000	1512163	1.005	34.14%	1.000	1476056	0.981
	25.32%	1697463	25.32%	1.000	1696997	1.000	23.59%	1.000	1683874	0.992
	40.49%	1744785	40.66%	1.000	1731681	0.992	37.47%	1.000	1741282	0.998
ex1221	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1222	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1223	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
ex1223a	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1223b	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
ex1224	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1225	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1226	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1233	62.21%	100	62.21%	1.000	100	1.000	62.21%	1.000	100	1.000
	0.36%	16235630	0.36%	1.000	16218406	0.999	0.38%	1.000	8635064	0.532
	1.18%	18982979	1.10%	1.000	18373453	0.968	1.06%	1.000	14121501	0.744
ex1243	3.40	551	3.40	1.000	551	1.000	3.40	1.000	551	1.000
	2.12	243	2.11	0.997	243	1.000	2.10	0.994	243	1.000
	3.43	594	3.43	1.000	594	1.000	3.38	0.989	594	1.000
ex1244	15.59	11571	15.53	0.996	11571	1.000	15.60	1.001	11571	1.000
	9.84	1873	9.77	0.994	1873	1.000	9.62	0.980	1655	**0.890**
ex1252	4.18	1328	4.25	1.014	1328	1.000	4.19	1.002	1328	1.000
	7.54	1341	7.52	0.998	1341	1.000	7.60	1.007	1341	1.000
ex1252a	11.05	1633	10.95	0.992	1633	1.000	10.94	0.991	1633	1.000
	7.25	1510	7.46	1.025	1510	1.000	7.28	1.004	1510	1.000
	5.75	1368	5.89	1.021	1368	1.000	5.89	1.021	1368	1.000
ex1263	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
ex1263a	0.50	56	0.50	1.000	78	*1.141*	0.50	1.000	57	1.006
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
ex1264	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1264a	0.50	13	0.50	1.000	13	1.000	0.50	1.000	13	1.000
	0.50	17	0.50	1.000	17	1.000	0.50	1.000	17	1.000
	0.50	15	0.50	1.000	15	1.000	0.50	1.000	15	1.000
ex1265	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1265a	0.50	59	0.50	1.000	59	1.000	0.50	1.000	54	0.969

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	13	0.50	1.000	13	1.000	0.50	1.000	13	1.000
	0.50	55	0.50	1.000	75	*1.129*	0.50	1.000	51	0.974
ex1266	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1266a	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	31	0.50	1.000	32	1.008	0.50	1.000	26	0.962
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex4	3.08	15	3.14	1.015	15	1.000	3.12	1.010	15	1.000
	3.61	5	3.65	1.009	5	1.000	3.66	1.011	5	1.000
	2.70	11	2.70	1.000	11	1.000	2.75	1.014	11	1.000
fac1	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
fac2	26.69	50356	19.15	**0.728**	29294	**0.583**	20.42	**0.774**	39182	**0.779**
	0.93	2	1.00	1.036	2	1.000	0.96	1.016	2	1.000
	0.95	4	0.95	1.000	4	1.000	0.93	0.990	4	1.000
fac3	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	6	0.50	1.000	6	1.000	0.50	1.000	6	1.000
	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
faclay20h	63.83%	99386	63.90%	1.000	103276	1.039	64.60%	1.000	95483	0.961
	51.83%	94276	52.33%	1.000	95790	1.016	52.33%	1.000	95795	1.016
	53.56%	98286	54.58%	1.000	98596	1.003	55.47%	1.000	99916	1.017
faclay25	170.28%	179414	168.58%	1.000	180057	1.004	177.36%	1.000	198399	1.106
	175.47%	195393	171.43%	1.000	297632	1.523	171.32%	1.000	155301	0.795
	132.33%	410625	129.79%	1.000	373818	0.910	131.42%	1.000	363228	0.885
faclay30	248.43%	140309	229.68%	1.000	151826	1.082	232.55%	1.000	87670	0.625
	283.25%	87871	258.90%	1.000	84651	0.963	279.31%	1.000	62027	0.706
	255.36%	97158	267.05%	1.000	22950	0.237	263.47%	1.000	23621	0.244
faclay30h	265.15%	3080	268.26%	1.000	3143	1.020	274.16%	1.000	3171	1.029
	281.34%	13047	275.22%	1.000	12377	0.949	275.52%	1.000	12262	0.940
	388.09%	3163	444.69%	1.000	2904	0.921	412.53%	1.000	10044	3.109
faclay33	414.86%	1227	388.50%	1.000	3888	3.005	366.51%	1.000	4324	3.334
	392.98%	4003	398.52%	1.000	1086	0.289	402.80%	1.000	4052	1.012

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	388.64%	3774	402.37%	1.000	1112	0.313	395.25%	1.000	3698	0.980
faclay35	604.93%	1538	564.04%	1.000	1587	1.030	534.59%	1.000	6817	4.223
	495.96%	6732	486.84%	1.000	5789	0.862	467.07%	1.000	6404	0.952
	596.82%	6961	553.75%	1.000	6113	0.880	552.76%	1.000	6513	0.937
faclay60	1848.00%	6	1848.00%	1.000	6	1.000	1848.00%	1.000	6	1.000
	1846.42%	4	1846.42%	1.000	4	1.000	1846.42%	1.000	4	1.000
	1848.57%	7	1848.57%	1.000	7	1.000	1848.57%	1.000	7	1.000
faclay70	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	2934.38%	1	2934.38%	1.000	1	1.000	2934.38%	1.000	1	1.000
	2781.44%	1	2781.44%	1.000	1	1.000	2781.44%	1.000	1	1.000
faclay75	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
faclay80	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
feedtray2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
feedtray	784.35%	27136	465.95%	1.000	44520	1.638	465.95%	1.000	23736	0.875
	465.95%	46465	465.95%	1.000	46276	0.996	465.95%	1.000	48680	1.048
	459.45%	10480	459.45%	1.000	10381	0.991	459.45%	1.000	8779	0.839
fin2bb	18.33	51	18.39	1.003	51	1.000	18.29	0.998	51	1.000
	56.20	300	56.40	1.003	300	1.000	201.96	*3.548*	4800	*12.250*
	111.06	5740	356.15	*3.187*	38020	*6.527*	75.13	**0.679**	790	**0.152**
flay02h	1.92	7	1.96	1.014	7	1.000	1.96	1.014	7	1.000
	1.54	7	1.53	0.996	7	1.000	1.55	1.004	7	1.000
	1.37	7	1.40	1.013	7	1.000	1.41	1.017	7	1.000
flay02m	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.64	7	0.64	1.000	7	1.000	0.63	0.994	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
flay03h	3.61	102	3.62	1.002	102	1.000	3.65	1.009	102	1.000
	3.24	111	3.20	0.991	111	1.000	3.22	0.995	111	1.000
	3.46	112	3.46	1.000	112	1.000	3.49	1.007	112	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
flay03m	1.68	103	1.65	0.989	103	1.000	1.68	1.000	103	1.000
	1.17	103	1.16	0.995	103	1.000	1.15	0.991	103	1.000
	1.35	105	1.39	1.017	105	1.000	1.38	1.013	105	1.000
flay04h	7.29	2027	7.53	1.029	2065	1.018	7.48	1.023	2075	1.023
	8.22	2063	7.57	**0.930**	2047	0.993	8.20	0.998	2159	1.044
	7.20	2159	6.99	0.974	2149	0.996	7.94	*1.090*	2193	1.015
flay04m	3.32	1825	3.31	0.998	1783	0.978	3.27	0.988	1849	1.012
	3.53	1939	3.54	1.002	1965	1.013	3.56	1.007	2042	*1.051*
	3.09	1943	3.27	1.044	1949	1.003	3.22	1.032	1949	1.003
flay05h	160.94	90925	172.65	*1.072*	97332	*1.070*	166.82	1.036	92281	1.015
	157.91	91358	159.43	1.010	92869	1.017	158.07	1.001	90556	0.991
	158.30	92763	173.26	*1.094*	98235	*1.059*	155.31	0.981	87982	**0.949**
flay05m	50.40	70558	51.55	1.022	68275	0.968	52.16	1.034	68868	0.976
	55.94	78017	51.79	**0.927**	70169	**0.900**	53.31	0.954	72578	**0.930**
	50.70	72731	52.63	1.037	70993	0.976	52.16	1.028	69430	0.955
flay06h	3.27%	4120321	3.77%	1.000	4017551	0.975	3.71%	1.000	4062096	0.986
	3.68%	4195096	3.49%	1.000	4158240	0.991	3.71%	1.000	4113926	0.981
	3.77%	3959672	3.76%	1.000	4006091	1.012	3.77%	1.000	3961523	1.000
flay06m	1813.53	3033105	1873.73	1.033	2977526	0.982	1887.75	1.041	3062342	1.010
	1916.53	3080877	1792.57	**0.935**	2845529	**0.924**	1788.18	**0.933**	2843589	**0.923**
	2384.13	3583282	1979.89	**0.831**	3082928	**0.860**	1995.36	**0.837**	3064705	**0.855**
fo7	72.88	111085	80.97	*1.110*	112231	1.010	73.84	1.013	81298	**0.732**
	176.00	268833	75.29	**0.431**	107218	**0.399**	79.06	**0.452**	110781	**0.412**
	100.09	134645	81.96	**0.821**	107113	**0.796**	71.77	**0.720**	91155	**0.677**
fo7_2	31.20	30959	40.68	*1.294*	36523	*1.179*	32.46	1.039	32575	*1.052*
	64.35	70170	38.93	**0.611**	35360	**0.505**	41.54	**0.651**	40838	**0.583**
	67.60	79711	80.61	*1.190*	98065	*1.230*	53.76	**0.798**	57713	**0.724**
fo7_ar25_1	27.07	42487	21.10	**0.787**	25897	**0.610**	17.71	**0.667**	22415	**0.529**
	40.06	52101	24.26	**0.615**	29666	**0.570**	25.83	**0.653**	32407	**0.623**
	16.21	19334	23.75	*1.438*	24692	*1.276*	17.32	*1.064*	19782	1.023
fo7_ar2_1	26.35	35861	18.13	**0.699**	24370	**0.680**	16.50	**0.640**	20219	**0.565**
	27.19	36527	22.50	**0.834**	32808	**0.898**	32.96	*1.205*	47234	*1.292*
	31.26	46261	27.99	**0.899**	47786	1.033	31.58	1.010	46929	1.014
fo7_ar3_1	37.48	52615	24.67	**0.667**	34670	**0.660**	33.98	**0.909**	42706	**0.812**

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	55.53	77778	40.62	**0.736**	55786	**0.718**	43.54	**0.788**	62641	**0.806**
	58.76	88997	32.72	**0.564**	45589	**0.513**	39.18	**0.672**	55876	**0.628**
fo7_ar4_1	69.93	99646	51.67	**0.743**	80370	**0.807**	79.08	*1.129*	97040	0.974
	51.70	67908	35.23	**0.687**	46448	**0.684**	43.53	**0.845**	59319	**0.874**
	68.43	91779	66.45	0.971	89993	0.981	44.73	**0.659**	54722	**0.597**
fo7_ar5_1	32.20	38340	21.23	**0.670**	22576	**0.590**	21.34	**0.673**	22092	**0.577**
	23.85	27827	25.86	*1.081*	27698	0.995	18.95	**0.803**	22660	**0.815**
	21.85	21815	33.61	*1.515*	37721	*1.726*	25.77	*1.172*	27520	*1.260*
fo8	484.24	770027	177.70	**0.368**	223395	**0.290**	163.30	**0.339**	198949	**0.258**
	233.54	308889	114.32	**0.492**	135234	**0.438**	128.88	**0.554**	176270	**0.571**
	100.46	133263	108.44	*1.079*	111913	**0.840**	59.33	**0.595**	62056	**0.466**
fo8_ar25_1	243.84	416948	154.79	**0.636**	250626	**0.601**	168.84	**0.694**	278321	**0.668**
	212.79	391313	129.22	**0.609**	221621	**0.566**	148.72	**0.700**	267562	**0.684**
	240.47	428064	157.99	**0.658**	275757	**0.644**	154.96	**0.646**	249676	**0.583**
fo8_ar2_1	181.61	370226	126.89	**0.700**	265440	**0.717**	140.98	**0.778**	274418	**0.741**
	151.82	284759	134.84	**0.889**	249302	**0.876**	141.58	**0.933**	274949	0.966
	127.81	240028	150.19	*1.174*	290895	*1.212*	149.87	*1.171*	286475	*1.193*
fo8_ar3_1	84.50	96319	32.58	**0.393**	29556	**0.308**	37.23	**0.447**	33245	**0.346**
	76.04	110915	37.32	**0.497**	46452	**0.419**	29.78	**0.400**	36352	**0.328**
	34.36	32478	42.24	*1.223*	42677	*1.313*	33.37	0.972	36197	*1.114*
fo8_ar4_1	130.05	187088	77.67	**0.600**	109382	**0.585**	112.31	**0.865**	160678	**0.859**
	98.49	130212	71.90	**0.733**	82158	**0.631**	40.32	**0.415**	38822	**0.299**
	74.96	99417	64.23	**0.859**	81775	**0.823**	84.72	*1.128*	116753	*1.174*
fo8_ar5_1	222.17	351697	108.43	**0.490**	167251	**0.476**	103.96	**0.470**	146264	**0.416**
	245.90	369577	169.60	**0.691**	242358	**0.656**	109.59	**0.448**	154677	**0.419**
	209.89	299992	133.76	**0.639**	191624	**0.639**	139.26	**0.665**	199354	**0.665**
fo9	840.34	1219849	645.45	**0.768**	916545	**0.751**	683.55	**0.814**	969543	**0.795**
	1156.15	1681207	724.68	**0.627**	1144200	**0.681**	486.53	**0.421**	753623	**0.448**
fo9_ar25_1	3150.98	5400537	4249.38	*1.348*	7124255	*1.319*	3188.23	1.012	5196800	0.962
	4270.66	6353464	3848.58	**0.901**	5637159	**0.887**	4082.44	0.956	5909450	**0.930**
	4382.88	6964783	2748.12	**0.627**	4741685	**0.681**	3663.53	**0.836**	5973269	**0.858**
fo9_ar2_1	1759.43	2849398	997.23	**0.567**	1695936	**0.595**	1107.47	**0.630**	1916407	**0.673**
	1762.32	2753859	1178.39	**0.669**	2004869	**0.728**	987.08	**0.560**	1703367	**0.619**
	1487.45	2584428	1133.92	**0.762**	2090806	**0.809**	1542.73	1.037	2739448	*1.060*

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
fo9_ar3_1	290.56	397690	71.90	**0.250**	81513	**0.205**	35.49	**0.125**	36484	**0.092**
	59.59	55540	45.64	**0.770**	45233	**0.815**	60.76	1.019	72881	*1.312*
	373.07	428449	103.04	**0.278**	118147	**0.276**	140.30	**0.378**	160574	**0.375**
fo9_ar4_1	637.01	766506	525.91	**0.826**	696770	**0.909**	589.02	**0.925**	815958	*1.065*
fo9_ar5_1	1163.42	1390307	426.68	**0.367**	534175	**0.384**	406.75	**0.350**	506954	**0.365**
	1172.70	1534693	493.09	**0.421**	600958	**0.392**	512.75	**0.438**	700738	**0.457**
	1432.20	1838362	1135.75	**0.793**	1363323	**0.742**	782.71	**0.547**	1010648	**0.550**
forest	41.82%	279	41.82%	1.000	279	1.000	41.82%	1.000	279	1.000
	37.18%	179328	37.18%	1.000	179328	1.000	37.18%	1.000	179328	1.000
	46.99%	3563	46.99%	1.000	3563	1.000	46.99%	1.000	3563	1.000
fuel	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
fuzzy	31.05%	93143	90.93%	1.000	56898	0.611	1.32%	1.000	153625	1.649
	161.92%	148846	90.84%	1.000	164252	1.103	107.35%	1.000	123575	0.830
	112.30%	264968	160.14%	1.000	568421	2.145	67.79%	1.000	291101	1.099
gabriel01	1639.27	1064655	747.37	**0.456**	456373	**0.429**	1338.69	**0.817**	907213	**0.852**
	1460.13	883835	1521.90	1.042	887496	1.004	963.61	**0.660**	580069	**0.656**
	1261.23	823355	1154.01	**0.915**	748078	**0.909**	1601.18	*1.269*	1035369	*1.257*
gabriel02	20.75%	2811181	24.61%	1.000	3005625	1.069	24.29%	1.000	3181170	1.132
	24.60%	3575768	20.49%	1.000	3440343	0.962	24.19%	1.000	3478488	0.973
	24.01%	2654329	24.04%	1.000	2543645	0.958	24.05%	1.000	2525686	0.952
gabriel04	1380.54	364531	4300.54	*3.114*	1360475	*3.731*	3722.31	*2.695*	1244199	*3.412*
	1917.11	534196	2259.29	*1.178*	609660	*1.141*	3038.36	*1.585*	1007034	*1.885*
	2334.23	623500	2044.77	**0.876**	573975	**0.921**	1878.55	**0.805**	498865	**0.800**
gabriel05	∞	1339390	∞	1.000	1364130	1.018	∞	1.000	1294562	0.967
	∞	1319363	∞	1.000	1429369	1.083	∞	1.000	1286070	0.975
	∞	1177014	∞	1.000	1138963	0.968	∞	1.000	1163958	0.989
gabriel06	∞	410602	∞	1.000	414646	1.010	∞	1.000	377144	0.919
	∞	350053	∞	1.000	404811	1.156	∞	1.000	355855	1.017
	∞	356183	∞	1.000	382311	1.073	∞	1.000	403162	1.132
gabriel07	∞	280757	∞	1.000	306760	1.093	∞	1.000	284999	1.015
	∞	274882	∞	1.000	157746	0.574	∞	1.000	231035	0.841
	∞	250709	∞	1.000	221588	0.884	∞	1.000	266231	1.062

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
gabriel08	∞	9583	∞	1.000	6177	0.648	∞	1.000	4754	0.501
	∞	11195	∞	1.000	8023	0.719	∞	1.000	4469	0.405
	∞	12879	∞	1.000	11124	0.865	∞	1.000	12453	0.967
gabriel09	19.02%	375880	19.55%	1.000	414320	1.102	19.06%	1.000	434335	1.155
	19.42%	421243	19.01%	1.000	457650	1.086	19.55%	1.000	437214	1.038
	21.71%	432595	21.43%	1.000	422888	0.978	22.25%	1.000	472365	1.092
gabriel10	2095.01%	1	2095.01%	1.000	1	1.000	2095.01%	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
gams01	4520.52%	215624	4497.43%	1.000	266254	1.235	4470.27%	1.000	259833	1.205
	4470.27%	283975	4931.09%	1.000	325257	1.145	4443.66%	1.000	294765	1.038
	4890.32%	107970	4860.98%	1.000	127965	1.185	5525.86%	1.000	126011	1.167
gams02	333.23%	48752	333.23%	1.000	48752	1.000	333.23%	1.000	48752	1.000
	312.81%	22236	312.81%	1.000	22236	1.000	312.81%	1.000	22236	1.000
	282.29%	34297	282.29%	1.000	34297	1.000	282.29%	1.000	34297	1.000
gams03	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	9794.65%	34	9794.65%	1.000	36	1.015	9794.65%	1.000	34	1.000
gasnet	∞	48448	∞	1.000	43980	0.908	∞	1.000	51759	1.068
	∞	49022	∞	1.000	48261	0.985	∞	1.000	48606	0.992
	93.77%	51253	93.77%	1.000	50385	0.983	96.89%	1.000	48176	0.940
gasnet_al1	3.04%	811877	3.04%	1.000	812648	1.001	3.04%	1.000	812138	1.000
	3.87%	1395011	3.87%	1.000	1398826	1.003	3.87%	1.000	1392994	0.999
	3.82%	880508	3.82%	1.000	882564	1.002	3.82%	1.000	879735	0.999
gasnet_al2	4.41%	971422	4.41%	1.000	976827	1.006	4.41%	1.000	972345	1.001
	4.60%	535084	4.60%	1.000	546023	1.020	4.60%	1.000	541653	1.012
	7.39%	1199521	7.39%	1.000	1211326	1.010	7.39%	1.000	1198830	0.999
gasnet_al3	1.65%	1286358	1.65%	1.000	1296137	1.008	1.65%	1.000	1276704	0.992
	2.52%	1583638	2.52%	1.000	1595242	1.007	2.52%	1.000	1582424	0.999
	5.11%	1017275	5.11%	1.000	1022446	1.005	5.11%	1.000	1004906	0.988
gasnet_al4	3.30%	1616745	3.30%	1.000	1647572	1.019	2.54%	1.000	1525636	0.944
	2.18%	1876547	2.18%	1.000	1888503	1.006	2.18%	1.000	1873322	0.998
	4.68%	1923757	4.68%	1.000	1929649	1.003	4.68%	1.000	1904503	0.990
gasprod_sarawak16	0.30%	1041083	0.31%	1.000	1254314	1.205	0.31%	1.000	1159259	1.114

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.87%	1027510	0.31%	1.000	1037276	1.010	0.21%	1.000	1137688	1.107
	0.39%	940162	0.39%	1.000	935667	0.995	0.27%	1.000	1251407	1.331
gasprod_sarawak81	0.39%	212381	0.39%	1.000	210077	0.989	0.40%	1.000	193007	0.909
	0.39%	157406	0.39%	1.000	172357	1.095	0.39%	1.000	202851	1.289
	0.93%	173610	0.93%	1.000	174491	1.005	0.93%	1.000	153829	0.886
gastrans040	2.94	24	2.99	1.013	24	1.000	2.86	0.980	24	1.000
	∞	50	∞	1.000	50	1.000	∞	1.000	50	1.000
	0.93	1	0.94	1.005	1	1.000	0.93	1.000	1	1.000
gastrans135	∞	204	∞	1.000	204	1.000	∞	1.000	300	1.316
	∞	111	∞	1.000	111	1.000	∞	1.000	111	1.000
	∞	63	∞	1.000	63	1.000	∞	1.000	63	1.000
gastrans582_cold13	24.15	23	24.32	1.007	23	1.000	24.10	0.998	23	1.000
	∞	4662	∞	1.000	3211	0.695	∞	1.000	2289	0.502
gastrans582_cold13_95	∞	290	∞	1.000	286	0.990	∞	1.000	288	0.995
	20.97	711	21.04	1.003	711	1.000	21.04	1.003	711	1.000
	15.81	39	15.82	1.001	39	1.000	15.74	0.996	39	1.000
gastrans582_cold17	13.37	1	13.43	1.004	1	1.000	13.49	1.008	1	1.000
	20.25	54	20.21	0.998	54	1.000	20.20	0.998	54	1.000
	∞	3555	∞	1.000	3555	1.000	∞	1.000	6501	1.806
gastrans582_cold17_95	∞	2047	∞	1.000	2372	1.151	∞	1.000	1965	0.962
	27.38	2	27.74	1.013	2	1.000	27.15	0.992	2	1.000
	39.43	73	39.54	1.003	73	1.000	39.22	0.995	73	1.000
gastrans582_cool12	∞	1275	∞	1.000	1191	0.939	∞	1.000	731	0.604
	14.71	143	14.81	1.006	143	1.000	14.78	1.004	133	0.959
	60.61	63	61.36	1.012	63	1.000	57.69	0.953	61	0.988
gastrans582_cool12_95	∞	9512	∞	1.000	8887	0.935	∞	1.000	1077	0.122
	43.81	2	44.14	1.007	2	1.000	44.18	1.008	2	1.000
gastrans582_cool14	∞	1182	29.58	**0.004**	30	**0.101**	∞	1.000	136	0.184
	∞	1805	∞	1.000	4199	2.257	∞	1.000	5121	2.741
	∞	9889	∞	1.000	24140	2.427	∞	1.000	149580	14.984
gastrans582_cool14_95	29.62	53	29.79	1.006	53	1.000	29.64	1.001	53	1.000
	∞	498	∞	1.000	498	1.000	29.59	**0.004**	14	**0.191**
gastrans582_freezing27	6938.34	201210	7023.64	1.012	199709	0.993	5933.10	**0.855**	173626	**0.863**
	154.80	1426	155.18	1.002	1426	1.000	135.56	**0.877**	731	**0.545**

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	126.65	1680	126.93	1.002	1680	1.000	127.33	1.005	1680	1.000
gastrans582_freezing27_95	∞	313757	∞	1.000	306685	0.977	∞	1.000	313864	1.000
	∞	76620	∞	1.000	97554	1.273	6634.08	**0.921**	150414	*1.962*
	3485.18	35241	3444.60	0.988	35241	1.000	3462.83	0.994	35241	1.000
gastrans582_freezing30	∞	1127	∞	1.000	1127	1.000	∞	1.000	1564	1.356
gastrans582_mild10	∞	2665	∞	1.000	3390	1.262	∞	1.000	3741	1.389
	∞	2307	∞	1.000	1633	0.720	∞	1.000	2301	0.998
gastrans582_mild10_95	32.40	1	32.45	1.001	1	1.000	32.09	0.991	1	1.000
	16.60	57	16.51	0.995	57	1.000	16.67	1.004	57	1.000
gastrans582_mild11	∞	59976	∞	1.000	49470	0.825	∞	1.000	5612	0.095
	∞	42238	∞	1.000	426	0.012	∞	1.000	849	0.022
	18.64	55	18.59	0.997	55	1.000	18.55	0.995	55	1.000
	∞	3700	∞	1.000	2574	0.704	∞	1.000	4239	1.142
gastrans582_warm15	23.75	6	23.90	1.006	6	1.000	23.69	0.998	6	1.000
	14.09	13	14.28	1.013	13	1.000	14.22	1.009	13	1.000
	∞	76	∞	1.000	76	1.000	∞	1.000	76	1.000
gastrans582_warm15_95	∞	1755	∞	1.000	1756	1.001	∞	1.000	1767	1.006
	1610.39	12549	∞	4.469	6669	0.535	∞	4.469	3359	0.273
	∞	1119	∞	1.000	1119	1.000	∞	1.000	1230	1.091
gastrans582_warm31	35.46	18	36.11	1.018	18	1.000	35.56	1.003	18	1.000
	∞	338	∞	1.000	340	1.005	∞	1.000	213	0.715
	45.11	66	45.42	1.007	66	1.000	45.07	0.999	66	1.000
gastrans582_warm31_95	∞	12989	∞	1.000	74532	5.702	∞	1.000	46040	3.525
	40.66	101	40.93	1.006	101	1.000	40.76	1.002	101	1.000
	∞	765	∞	1.000	1304	1.623	∞	1.000	7546	8.839
gastrans	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
gbd	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
gear2	0.50	17	0.50	1.000	17	1.000	0.50	1.000	17	1.000
	0.50	17	0.50	1.000	17	1.000	0.50	1.000	17	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	17	0.50	1.000	17	1.000	0.50	1.000	17	1.000
gear3	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
gear4	0.96	4579	0.94	0.990	4579	1.000	0.99	1.015	4579	1.000
	0.90	4579	0.99	1.047	4579	1.000	1.02	*1.063*	4579	1.000
	0.96	4579	1.02	1.031	4579	1.000	0.98	1.010	4579	1.000
gear	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
genpooling_lee1	4.15	2292	4.02	0.975	2292	1.000	4.10	0.990	2292	1.000
	13.25	29271	13.50	1.018	29271	1.000	13.41	1.011	29271	1.000
	6.23	4639	6.20	0.996	4639	1.000	6.22	0.999	4639	1.000
genpooling_lee2	97.22	68646	97.05	0.998	68646	1.000	97.27	1.001	68646	1.000
	64.83	38240	64.89	1.001	38240	1.000	65.30	1.007	38240	1.000
	35.63	24343	35.91	1.008	24343	1.000	37.23	1.044	23718	0.974
genpooling_meyer04	102.25%	1207847	92.00%	1.000	1282861	1.062	73.50%	1.000	1448789	1.199
	84.25%	1283334	91.52%	1.000	1251023	0.975	88.19%	1.000	1266565	0.987
	121.88%	1233194	128.61%	1.000	1252940	1.016	74.67%	1.000	1279278	1.037
genpooling_meyer10	98.83%	1339149	158.33%	1.000	1263706	0.944	96.82%	1.000	1240703	0.926
	144.12%	1243942	113.73%	1.000	1284940	1.033	96.69%	1.000	1282438	1.031
	148.43%	1387695	112.00%	1.000	1278237	0.921	111.59%	1.000	1383423	0.997
genpooling_meyer15	84.03%	1127876	91.88%	1.000	1083989	0.961	69.66%	1.000	1219518	1.081
	97.39%	1031027	106.08%	1.000	1035234	1.004	89.43%	1.000	1157177	1.122
	90.41%	1100311	122.49%	1.000	1097595	0.998	84.41%	1.000	1236617	1.124
ghg_1veh	9.26	1402	9.12	0.986	1402	1.000	9.14	0.988	1402	1.000
	10.31	1732	10.15	0.986	1732	1.000	10.29	0.998	1732	1.000
gkocis	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
graphpart_2g-0044-1601	1.14	11	1.14	1.000	11	1.000	1.14	1.000	11	1.000
	0.62	23	0.64	1.012	23	1.000	0.64	1.012	23	1.000
	0.58	19	0.60	1.013	19	1.000	0.57	0.994	19	1.000
graphpart_2g-0055-0062	3.02	166	3.01	0.998	166	1.000	3.09	1.017	166	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	3.33	159	3.32	0.998	159	1.000	3.24	0.979	159	1.000
	5.00	209	5.01	1.002	209	1.000	5.01	1.002	209	1.000
graphpart_2g-0066-0066	41.36	705	40.74	0.985	705	1.000	41.08	0.993	705	1.000
	58.86	1117	58.10	0.987	1117	1.000	58.77	0.998	1117	1.000
	56.04	991	55.10	0.984	991	1.000	56.01	0.999	991	1.000
graphpart_2g-0077-0077	562.78	6789	556.29	0.988	6789	1.000	562.00	0.999	6789	1.000
	776.72	8617	768.67	0.990	8617	1.000	776.32	0.999	8617	1.000
	668.60	8093	715.48	*1.070*	9112	*1.124*	873.29	*1.306*	11396	*1.403*
graphpart_2g-0088-0088	3.65%	29817	3.64%	1.000	29914	1.003	3.80%	1.000	28649	0.961
	3.85%	18260	3.83%	1.000	18548	1.016	3.86%	1.000	18197	0.997
	3.79%	26772	3.76%	1.000	27107	1.012	3.78%	1.000	26846	1.003
graphpart_2g-0099-9211	31.89%	10938	31.89%	1.000	10990	1.005	31.89%	1.000	10885	0.995
	29.48%	11767	30.64%	1.000	12047	1.024	27.84%	1.000	11956	1.016
	30.99%	10639	30.99%	1.000	10708	1.006	30.99%	1.000	10668	1.003
graphpart_2g-1010-0824	77.57%	590	77.57%	1.000	590	1.000	77.57%	1.000	590	1.000
	64.36%	490	64.36%	1.000	497	1.012	64.37%	1.000	470	0.966
	27.51%	1329	27.51%	1.000	1339	1.007	27.51%	1.000	1329	1.000
graphpart_2pm-0044-0044	0.50	224	0.50	1.000	214	0.969	0.50	1.000	118	**0.673**
	0.50	122	0.50	1.000	136	*1.063*	0.50	1.000	125	1.014
	0.50	123	0.50	1.000	123	1.000	0.50	1.000	123	1.000
graphpart_2pm-0055-0055	1.59	1305	1.75	*1.062*	1533	*1.162*	1.74	*1.058*	1533	*1.162*
	1.65	1210	1.80	*1.057*	1377	*1.127*	1.90	*1.094*	1373	*1.124*
	2.16	975	2.87	*1.225*	1052	*1.072*	2.78	*1.196*	1052	*1.072*
graphpart_2pm-0066-0066	2.29	884	2.22	0.979	954	*1.071*	2.20	0.973	954	*1.071*
	2.60	1005	2.14	**0.872**	750	**0.769**	2.08	**0.856**	750	**0.769**
	2.04	896	2.29	*1.082*	948	*1.052*	2.30	*1.086*	948	*1.052*
graphpart_2pm-0077-0777	10.20	1935	10.78	*1.052*	2334	*1.196*	10.82	*1.055*	2334	*1.196*
	6.14	1283	6.52	*1.053*	1392	*1.079*	6.43	1.041	1392	*1.079*
	11.01	3758	13.98	*1.247*	4342	*1.151*	14.10	*1.257*	4342	*1.151*
graphpart_2pm-0088-0888	6.39	2299	8.27	*1.254*	2725	*1.178*	8.24	*1.250*	2725	*1.178*
	13.03	4953	9.56	**0.753**	3729	**0.758**	9.70	**0.763**	3729	**0.758**
	9.73	2422	10.79	*1.099*	2423	1.000	10.69	*1.089*	2423	1.000
graphpart_2pm-0099-0999	52.13	6870	100.05	*1.902*	8222	*1.194*	99.27	*1.887*	8404	*1.220*
	79.90	10837	64.33	**0.808**	10984	1.013	62.55	**0.786**	10890	1.005

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	46.03	5296	65.34	*1.411*	10046	*1.880*	61.54	*1.330*	9166	*1.717*
graphpart_3g-0234-0234	12.46	337	12.33	0.990	337	1.000	12.53	1.005	337	1.000
	13.35	235	12.94	0.971	235	1.000	13.33	0.999	235	1.000
	13.51	248	13.37	0.990	248	1.000	13.47	0.997	248	1.000
graphpart_3g-0244-0244	42.12	345	41.33	0.982	345	1.000	42.19	1.002	345	1.000
	71.52	758	70.20	0.982	758	1.000	71.66	1.002	758	1.000
	42.42	431	41.59	0.981	431	1.000	42.52	1.002	431	1.000
graphpart_3g-0333-0333	19.00	521	24.43	*1.272*	661	*1.225*	26.25	*1.363*	712	*1.308*
	15.44	373	15.43	0.999	373	1.000	15.58	1.009	373	1.000
	38.50	809	37.77	0.982	809	1.000	38.53	1.001	809	1.000
graphpart_3g-0334-0334	455.57	5552	461.29	1.013	5892	*1.060*	448.51	0.985	5585	1.006
	598.02	7362	591.31	0.989	7362	1.000	548.27	**0.917**	6502	**0.885**
	527.85	6929	520.70	0.986	6929	1.000	529.57	1.003	6929	1.000
graphpart_3g-0344-0344	2576.81	13593	2549.49	0.989	13593	1.000	2577.99	1.000	13593	1.000
	2226.84	13447	2204.07	0.990	13447	1.000	2821.42	*1.267*	16222	*1.205*
	3278.45	17973	3224.51	0.984	17973	1.000	3246.82	0.990	17973	1.000
graphpart_3g-0444-0444	20.02%	7632	20.00%	1.000	7663	1.004	20.00%	1.000	7651	1.002
	18.68%	7038	18.68%	1.000	7074	1.005	18.76%	1.000	7004	0.995
	19.01%	6561	19.01%	1.000	6561	1.000	19.01%	1.000	6561	1.000
graphpart_3pm-0234-0234	4.90	1381	5.59	*1.117*	1907	*1.355*	5.66	*1.129*	1907	*1.355*
	1.56	856	1.55	0.996	862	1.006	1.60	1.016	862	1.006
	1.39	886	1.56	*1.071*	873	0.987	1.58	*1.079*	873	0.987
graphpart_3pm-0244-0244	23.41	5072	24.21	1.033	5118	1.009	24.32	1.037	5118	1.009
	21.43	5623	21.09	0.985	4282	**0.766**	21.13	0.987	4282	**0.766**
	16.57	4163	16.87	1.017	3644	**0.878**	16.92	1.020	3644	**0.878**
graphpart_3pm-0333-0333	11.99	2647	12.00	1.001	2922	*1.100*	11.62	0.972	2922	*1.100*
	6.64	1632	5.70	**0.877**	1459	**0.900**	5.64	**0.869**	1459	**0.900**
	7.49	2406	8.68	*1.140*	2610	*1.081*	8.70	*1.143*	2610	*1.081*
graphpart_3pm-0334-0334	57.75	12719	66.07	*1.142*	15360	*1.206*	66.34	*1.146*	15360	*1.206*
	47.17	14351	49.27	1.044	17871	*1.244*	49.73	*1.053*	17934	*1.248*
	58.75	23508	67.51	*1.147*	25352	*1.078*	67.36	*1.144*	25352	*1.078*
graphpart_3pm-0344-0344	666.67	317554	636.98	0.956	360039	*1.134*	636.31	0.955	360039	*1.134*
	436.24	215740	606.83	*1.390*	295908	*1.371*	606.40	*1.389*	295908	*1.371*
	985.75	334535	1083.79	*1.099*	404051	*1.208*	1084.89	*1.100*	404051	*1.208*

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
graphpart_3pm-0444-0444	14.71%	3523996	17.91%	1.000	3537573	1.004	17.65%	1.000	3549896	1.007
	19.82%	3002615	17.82%	1.000	2851818	0.950	17.80%	1.000	2875151	0.958
	20.18%	2508832	21.13%	1.000	2347921	0.936	20.24%	1.000	2689197	1.072
graphpart_clique-20	12.77	2743	11.49	**0.907**	3085	*1.120*	11.65	**0.919**	3085	*1.120*
	14.25	3371	13.00	**0.918**	3126	**0.929**	13.05	**0.921**	3126	**0.929**
	11.77	2667	13.88	*1.165*	3068	*1.145*	14.19	*1.190*	3068	*1.145*
graphpart_clique-30	173.26	40952	110.90	**0.642**	23676	**0.579**	116.60	**0.675**	24833	**0.607**
	98.78	15190	94.49	0.957	15398	1.014	97.92	0.991	14221	**0.937**
	180.55	19713	138.43	**0.768**	16498	**0.838**	162.23	**0.899**	18544	**0.941**
graphpart_clique-40	861.40	506741	785.11	**0.912**	474902	**0.937**	660.55	**0.767**	401476	**0.792**
	962.71	624930	1241.52	*1.289*	697242	*1.116*	1532.65	*1.591*	819272	*1.311*
	772.68	368811	671.33	**0.869**	271075	**0.735**	723.20	**0.936**	321347	**0.871**
graphpart_clique-50	168.77%	3657206	165.32%	1.000	3104211	0.849	131.12%	1.000	4421349	1.209
	5629.60	2611816	30.03%	1.279	3430322	1.313	6619.20	*1.176*	2561406	0.981
	5990.57	2554840	37.96%	1.202	3190804	1.249	5697.56	0.951	2464068	0.964
graphpart_clique-60	412.12%	985368	555.89%	1.000	735131	0.746	399.73%	1.000	863317	0.876
	386.84%	843859	650.35%	1.000	961458	1.139	472.13%	1.000	1162398	1.377
	374.84%	782240	1141.91%	1.000	789869	1.010	355.40%	1.000	720172	0.921
graphpart_clique-70	3574.38%	598380	3125.47%	1.000	543864	0.909	2744.45%	1.000	448699	0.750
	1739.22%	669819	2951.62%	1.000	384190	0.574	2341.95%	1.000	562137	0.839
	624.45%	493360	1557.56%	1.000	602448	1.221	1267.18%	1.000	521735	1.058
hadamard_4	0.50	139	0.50	1.000	139	1.000	0.50	1.000	139	1.000
	0.50	139	0.50	1.000	139	1.000	0.50	1.000	139	1.000
	0.50	139	0.50	1.000	139	1.000	0.50	1.000	139	1.000
hadamard_5	56.87	84303	59.60	1.047	80984	0.961	60.29	*1.059*	80984	0.961
	57.14	84303	59.72	1.044	80984	0.961	60.31	*1.055*	80984	0.961
	56.92	84303	59.60	1.046	80984	0.961	60.61	*1.064*	80984	0.961
hadamard_6	977.78%	2574288	983.33%	1.000	2452758	0.953	986.11%	1.000	2418339	0.939
	974.07%	2608338	982.61%	1.000	2468644	0.946	986.11%	1.000	2420785	0.928
	977.78%	2578978	981.48%	1.000	2480348	0.962	985.19%	1.000	2431194	0.943
hadamard_7	$\geq$ 10000%	5891	$\geq$ 10000%	1.000	6762	1.145	$\geq$ 10000%	1.000	6842	1.159
	$\geq$ 10000%	5804	$\geq$ 10000%	1.000	6818	1.172	$\geq$ 10000%	1.000	6841	1.176
	$\geq$ 10000%	5804	$\geq$ 10000%	1.000	6841	1.176	$\geq$ 10000%	1.000	6841	1.176
hadamard_8	∞	8	∞	1.000	8	1.000	∞	1.000	8	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	8	∞	1.000	8	1.000	∞	1.000	8	1.000
	∞	8	∞	1.000	8	1.000	∞	1.000	8	1.000
hadamard_9	∞	0	∞	1.000	0	1.000	∞	1.000	0	1.000
	∞	0	∞	1.000	0	1.000	∞	1.000	0	1.000
	∞	0	∞	1.000	0	1.000	∞	1.000	0	1.000
hda	1097.33%	34929	1097.33%	1.000	34929	1.000	∞	1.000	258966	7.396
	332.34%	437952	331.25%	1.000	441243	1.008	392.66%	1.000	394423	0.901
	∞	51	∞	1.000	51	1.000	∞	1.000	51	1.000
heatexch_gen2	∞	9256	∞	1.000	9256	1.000	∞	1.000	9256	1.000
	∞	8839	∞	1.000	8839	1.000	∞	1.000	8839	1.000
heatexch_gen3	∞	1094	∞	1.000	1094	1.000	∞	1.000	1094	1.000
	∞	3090	∞	1.000	3220	1.041	∞	1.000	3025	0.980
	∞	14498	∞	1.000	14498	1.000	∞	1.000	3051	0.216
heatexch_spec1	1.12%	4558327	1.12%	1.000	4577107	1.004	1.12%	1.000	5088443	1.116
	1.38%	5815842	1.38%	1.000	4724880	0.812	0.98%	1.000	3797154	0.653
	0.69%	6669693	0.69%	1.000	6667622	1.000	0.70%	1.000	7573331	1.135
heatexch_spec2	6.56%	4077931	13.98%	1.000	3089298	0.758	46.67%	1.000	1681226	0.412
	4.78%	2259499	42.73%	1.000	118376	0.052	44.98%	1.000	7003	0.003
heatexch_spec3	60.34%	2891526	78.47%	1.000	2343573	0.811	55.43%	1.000	2075563	0.718
	77.98%	2291921	89.56%	1.000	1928623	0.841	54.29%	1.000	2109767	0.921
hmittelman	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
hvb11	24.17	5640	24.44	1.011	5749	1.019	24.27	1.004	5749	1.019
	12.66	1644	13.01	1.026	1859	*1.123*	13.13	1.034	1859	*1.123*
	12.17	1117	11.84	0.975	917	**0.836**	11.89	0.979	917	**0.836**
hybriddynamic_fixed	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
hybriddynamic_var	1.86	2021	1.75	0.962	2021	1.000	1.39	**0.836**	821	**0.434**
	1.72	1961	1.70	0.993	1961	1.000	1.44	**0.897**	761	**0.418**
	1.73	1781	1.75	1.007	1781	1.000	1.49	**0.912**	1046	**0.609**
hydroenergy1	3114.14	3348551	3179.45	1.021	3348551	1.000	3158.11	1.014	3342201	0.998
	0.01%	7915235	0.01%	1.000	7756222	0.980	0.01%	1.000	7796952	0.985

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	4368.26	4613451	4439.31	1.016	4613451	1.000	4395.87	1.006	4613451	1.000
hydroenergy2	0.75%	2097781	0.75%	1.000	2090479	0.997	0.75%	1.000	2089060	0.996
	0.67%	1873677	0.67%	1.000	1881288	1.004	0.67%	1.000	1868048	0.997
	1.01%	1934855	1.01%	1.000	1937788	1.002	1.01%	1.000	1928201	0.997
hydroenergy3	1.91%	616940	1.91%	1.000	620851	1.006	1.91%	1.000	618340	1.002
	1.89%	610174	1.89%	1.000	615957	1.009	1.89%	1.000	609640	0.999
	1.82%	642464	1.82%	1.000	649576	1.011	1.82%	1.000	641092	0.998
ising2_5-300_5555	9863.59%	76	9867.62%	1.000	66	0.943	9864.36%	1.000	69	0.960
	9863.59%	76	9867.62%	1.000	66	0.943	9864.36%	1.000	69	0.960
	9863.59%	76	9867.62%	1.000	66	0.943	9864.36%	1.000	69	0.960
jit1	0.50	158	0.50	1.000	158	1.000	0.50	1.000	158	1.000
	0.50	158	0.50	1.000	158	1.000	0.50	1.000	158	1.000
	0.50	158	0.50	1.000	158	1.000	0.50	1.000	158	1.000
kport20	661.02	606741	1221.35	*1.846*	1003723	*1.654*	495.64	**0.750**	571892	**0.943**
	722.40	704971	728.58	1.009	688341	0.976	388.71	**0.539**	339688	**0.482**
	5.58%	1688868	1.28%	1.000	3126586	1.851	1902.94	**0.264**	761986	**0.451**
kport40	26.38%	352155	28.36%	1.000	345821	0.982	23.01%	1.000	330083	0.937
	26.44%	282983	26.34%	1.000	285977	1.011	25.79%	1.000	285532	1.009
	23.91%	413370	18.70%	1.000	396904	0.960	23.94%	1.000	355601	0.860
lip	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
lop97ic	75.65%	101986	75.65%	1.000	105049	1.030	75.65%	1.000	105327	1.033
	73.71%	98706	79.74%	1.000	99116	1.004	75.12%	1.000	100489	1.018
	79.52%	93428	83.01%	1.000	97380	1.042	82.97%	1.000	96329	1.031
lop97icx	50.91%	89722	49.93%	1.000	88783	0.990	50.25%	1.000	92707	1.033
	49.84%	83686	50.45%	1.000	86210	1.030	52.20%	1.000	86133	1.029
	47.47%	111141	50.76%	1.000	93158	0.838	50.34%	1.000	88452	0.796
m3	0.90	7	0.84	0.968	7	1.000	0.89	0.995	7	1.000
	0.57	15	0.59	1.013	15	1.000	0.58	1.006	15	1.000
	1.13	9	1.12	0.995	9	1.000	1.14	1.005	9	1.000
m6	1.51	244	1.71	*1.080*	257	1.038	1.62	1.044	259	1.044
	1.59	168	1.78	*1.073*	130	**0.858**	1.80	*1.081*	130	**0.858**
	3.17	956	1.90	**0.695**	663	**0.723**	2.22	**0.772**	724	**0.780**

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Table E.1: Detailed computational results on MINLPLIB.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
m7	3.61	499	4.10	*1.106*	504	1.008	3.62	1.002	329	**0.716**
	5.19	1102	4.11	**0.826**	880	**0.815**	4.57	**0.900**	864	**0.802**
	4.68	1430	4.71	1.005	1418	0.992	4.53	0.974	1381	0.968
m7_ar25_1	1.31	759	1.59	*1.121*	544	**0.750**	1.37	1.026	536	**0.740**
	1.78	733	1.59	**0.932**	676	**0.932**	1.59	**0.932**	613	**0.856**
	1.38	669	1.33	0.979	576	**0.879**	0.72	**0.723**	543	**0.836**
m7_ar2_1	4.53	5695	4.34	0.966	5546	0.974	5.41	*1.159*	5507	0.968
	6.96	6701	5.95	**0.873**	5948	**0.889**	5.04	**0.759**	5757	**0.861**
	5.22	5949	5.16	0.990	6387	*1.072*	5.68	*1.074*	5910	0.994
m7_ar3_1	7.37	5746	7.60	1.027	5440	**0.948**	8.19	*1.098*	5837	1.016
	7.13	6245	5.71	**0.825**	3937	**0.636**	5.66	**0.819**	4306	**0.694**
	7.65	7043	8.32	*1.077*	8077	*1.145*	9.32	*1.193*	7487	*1.062*
m7_ar4_1	2.94	1028	2.26	**0.827**	1124	*1.085*	2.24	**0.822**	978	0.956
	2.78	656	2.61	0.955	551	**0.861**	1.92	**0.772**	581	**0.901**
	2.09	394	2.44	*1.113*	682	*1.583*	2.17	1.026	636	*1.490*
m7_ar5_1	5.95	4140	6.58	*1.091*	4083	0.987	7.31	*1.196*	4090	0.988
	3.99	2760	6.48	*1.499*	4066	*1.457*	6.74	*1.551*	3671	*1.319*
	3.78	1837	2.76	**0.787**	1733	**0.946**	3.05	**0.847**	1682	**0.920**
maxcsp-ehi-85-297-12	∞	655142	∞	1.000	721408	1.101	∞	1.000	622828	0.951
	∞	687216	∞	1.000	505390	0.735	∞	1.000	500609	0.728
	∞	901666	∞	1.000	823926	0.914	∞	1.000	829639	0.920
maxcsp-ehi-85-297-36	∞	752895	∞	1.000	776770	1.032	∞	1.000	730802	0.971
	∞	588313	∞	1.000	671770	1.142	∞	1.000	590979	1.005
	∞	801010	∞	1.000	716147	0.894	∞	1.000	869577	1.086
maxcsp-ehi-85-297-71	∞	634607	∞	1.000	657972	1.037	∞	1.000	543020	0.856
	∞	721949	∞	1.000	732350	1.014	∞	1.000	788776	1.093
	∞	667593	∞	1.000	583054	0.873	∞	1.000	613972	0.920
maxcsp-ehi-90-315-70	∞	770987	∞	1.000	822859	1.067	∞	1.000	780342	1.012
	∞	879799	∞	1.000	757279	0.861	∞	1.000	733830	0.834
	∞	604475	∞	1.000	585488	0.969	∞	1.000	566971	0.938
maxcsp-geo50-20-d4-75-36	800.59	199203	1457.99	*1.820*	347152	*1.742*	1080.99	*1.350*	279086	*1.401*
	604.20	145140	814.13	*1.347*	202548	*1.395*	351.25	**0.582**	86199	**0.594**
	371.47	99502	508.48	*1.368*	122684	*1.233*	488.64	*1.315*	120814	*1.214*
maxcsp-langford-3-11	∞	4388833	∞	1.000	3859341	0.879	∞	1.000	3750352	0.855

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	4068541	∞	1.000	4095812	1.007	∞	1.000	3812836	0.937
	∞	4172074	∞	1.000	4381033	1.050	∞	1.000	4085243	0.979
mbtd	236.67%	463	223.33%	1.000	629	1.295	190.00%	1.000	764	1.535
	173.33%	1357	196.67%	1.000	918	0.699	180.00%	1.000	1193	0.887
	233.34%	715	246.67%	1.000	714	0.999	183.33%	1.000	500	0.736
meanvar-orl400_05_e_8	130.95	78273	132.89	1.015	78773	1.006	130.90	1.000	75593	0.966
	143.63	91674	124.71	**0.869**	66034	**0.721**	75.42	**0.528**	2708	**0.031**
	120.17	77632	106.76	**0.889**	55112	**0.710**	120.33	1.001	75362	0.971
meanvarx	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
milinfract	56.13	9	56.07	0.999	9	1.000	55.98	0.997	9	1.000
	92.45	2	92.32	0.999	2	1.000	91.95	0.995	2	1.000
	51.33	2	51.10	0.996	2	1.000	51.64	1.006	2	1.000
minlphix	∞	45177	∞	1.000	45177	1.000	∞	1.000	45177	1.000
	∞	94160	∞	1.000	94160	1.000	∞	1.000	94160	1.000
multiplants_mtg1b	168.34%	355737	155.12%	1.000	352459	0.991	147.83%	1.000	334594	0.941
	168.20%	360834	138.18%	1.000	358180	0.993	120.78%	1.000	364797	1.011
	156.41%	391997	184.18%	1.000	358423	0.914	152.08%	1.000	330729	0.844
multiplants_mtg1c	563.92%	338095	524.04%	1.000	305818	0.905	524.02%	1.000	300346	0.888
	506.79%	341383	482.87%	1.000	308021	0.902	504.17%	1.000	303445	0.889
multiplants_mtg5	25.45%	919872	23.09%	1.000	125530	0.137	6.36%	1.000	914752	0.994
	18.65%	1194683	16.58%	1.000	1338563	1.120	8.19%	1.000	1216753	1.018
	12.59%	953152	18.98%	1.000	1102076	1.156	19.54%	1.000	1011344	1.061
multiplants_mtg6	15.79%	706962	14.34%	1.000	531987	0.753	13.61%	1.000	462163	0.654
	15.31%	625728	14.92%	1.000	610518	0.976	14.38%	1.000	467375	0.747
	15.04%	641369	14.25%	1.000	495729	0.773	14.40%	1.000	415514	0.648
multiplants_stg1	∞	309	∞	1.000	306	0.993	∞	1.000	309	1.000
	∞	609	∞	1.000	608	0.999	∞	1.000	609	1.000
	∞	34	∞	1.000	34	1.000	∞	1.000	34	1.000
multiplants_stg1a	∞	1154	∞	1.000	222	0.257	∞	1.000	1206	1.041
	∞	7837	∞	1.000	1535	0.206	∞	1.000	1523	0.204
	∞	1260	∞	1.000	423	0.385	∞	1.000	262	0.266
multiplants_stg1b	∞	2054	∞	1.000	2045	0.996	∞	1.000	2063	1.004

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	561	∞	1.000	561	1.000	∞	1.000	561	1.000
	∞	4617	∞	1.000	4591	0.994	∞	1.000	4630	1.003
multiplants_stg1c	∞	1329	∞	1.000	233	0.233	∞	1.000	233	0.233
	∞	2083	∞	1.000	1818	0.879	∞	1.000	2389	1.140
	∞	3000	∞	1.000	2621	0.878	∞	1.000	1908	0.648
multiplants_stg5	∞	479	∞	1.000	479	1.000	∞	1.000	479	1.000
	∞	2808	∞	1.000	3530	1.248	∞	1.000	2758	0.983
	∞	1315	∞	1.000	158	0.182	∞	1.000	237	0.238
multiplants_stg6	∞	143	∞	1.000	143	1.000	∞	1.000	143	1.000
	∞	343	∞	1.000	343	1.000	∞	1.000	345	1.005
ndcc12	∞	315450	∞	1.000	298149	0.945	∞	1.000	216516	0.686
	∞	221586	∞	1.000	150924	0.681	∞	1.000	271025	1.223
	∞	279688	∞	1.000	140610	0.503	∞	1.000	150055	0.537
ndcc12persp	∞	2231301	∞	1.000	2359692	1.058	∞	1.000	1104230	0.495
	∞	1318647	∞	1.000	912331	0.692	∞	1.000	1166865	0.885
	∞	1407899	∞	1.000	661317	0.470	∞	1.000	1169783	0.831
ndcc13	25.15%	519639	23.08%	1.000	165929	0.319	25.15%	1.000	323364	0.622
	25.62%	415375	40.04%	1.000	10556	0.026	27.65%	1.000	410142	0.987
	24.83%	384762	23.08%	1.000	1610194	4.184	23.08%	1.000	1224070	3.181
ndcc13persp	31.19%	613391	32.14%	1.000	499371	0.814	28.76%	1.000	806522	1.315
	19.18%	698637	22.84%	1.000	406496	0.582	19.56%	1.000	885473	1.267
	25.27%	380482	23.01%	1.000	698702	1.836	22.80%	1.000	597549	1.570
ndcc14	90.90%	11149	85.89%	1.000	29873	2.665	89.85%	1.000	30443	2.715
	93.94%	8896	91.88%	1.000	23519	2.626	90.63%	1.000	37588	4.189
	82.75%	93550	83.93%	1.000	24652	0.264	92.34%	1.000	17243	0.185
ndcc14persp	89.17%	1089278	87.16%	1.000	977923	0.898	90.73%	1.000	846506	0.777
	80.36%	927503	81.22%	1.000	925903	0.998	80.83%	1.000	729191	0.786
	94.07%	1515724	94.35%	1.000	1302435	0.859	93.54%	1.000	743083	0.490
ndcc15	26.42%	24853	25.51%	1.000	22726	0.915	25.58%	1.000	22400	0.902
	26.90%	32485	25.40%	1.000	30636	0.943	25.03%	1.000	41949	1.290
	30.21%	10824	25.85%	1.000	28872	2.652	25.00%	1.000	27204	2.499
ndcc15persp	29.69%	747922	31.05%	1.000	568272	0.760	26.88%	1.000	724582	0.969
	28.99%	873424	27.74%	1.000	512133	0.586	25.95%	1.000	490760	0.562
	∞	342692	30.95%	1.000	521997	1.523	∞	1.000	1081146	3.154

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
ndcc16	100.04%	32557	99.59%	1.000	52965	1.625	100.42%	1.000	30016	0.922
	∞	79647	∞	1.000	32848	0.413	∞	1.000	79827	1.002
	100.08%	86303	101.58%	1.000	45250	0.525	99.42%	1.000	57826	0.670
ndcc16persp	∞	780591	∞	1.000	405606	0.520	∞	1.000	553549	0.709
	∞	635644	∞	1.000	548364	0.863	∞	1.000	591876	0.931
	∞	665085	∞	1.000	730866	1.099	∞	1.000	273005	0.411
netmod_dol1	1416.41	54697	1361.53	0.961	57270	1.047	1376.50	0.972	56761	1.038
	1489.41	56665	1545.72	1.038	55632	0.982	1625.62	*1.091*	56260	0.993
	2169.71	53806	2110.93	0.973	56110	1.043	2147.23	0.990	52948	0.984
netmod_dol2	38.68	224	33.30	**0.864**	158	**0.796**	33.77	**0.876**	158	**0.796**
	38.99	218	37.94	0.974	214	0.987	38.89	0.997	214	0.987
	38.73	143	38.55	0.995	141	0.992	39.16	1.011	141	0.992
netmod_kar1	7.82	470	6.83	**0.888**	455	0.974	6.90	**0.896**	455	0.974
	8.52	397	9.82	*1.137*	498	*1.203*	9.95	*1.150*	498	*1.203*
	10.78	441	8.71	**0.824**	386	**0.898**	8.76	**0.829**	386	**0.898**
netmod_kar2	7.84	470	6.86	**0.889**	455	0.974	6.87	**0.890**	455	0.974
	8.49	397	9.83	*1.141*	498	*1.203*	9.93	*1.152*	498	*1.203*
	10.71	441	8.70	**0.828**	386	**0.898**	8.83	**0.839**	386	**0.898**
no7_ar25_1	34.63	43187	37.53	*1.081*	49769	*1.152*	35.26	1.018	44506	1.030
	42.10	58532	34.86	**0.832**	40805	**0.698**	38.87	**0.925**	54454	**0.930**
	44.23	48245	41.42	**0.938**	48124	0.997	41.95	**0.950**	49287	1.022
no7_ar2_1	23.36	26120	22.07	**0.947**	28662	*1.097*	18.71	**0.809**	19042	**0.730**
	20.97	23800	18.71	**0.897**	20018	**0.842**	21.06	1.004	24414	1.026
	19.14	21929	19.88	1.037	21463	0.979	17.28	**0.908**	18392	**0.839**
no7_ar3_1	206.35	393305	133.04	**0.646**	239753	**0.610**	100.39	**0.489**	165927	**0.422**
	133.08	224981	117.85	**0.886**	206142	**0.916**	107.62	**0.810**	186254	**0.828**
	110.97	194374	111.03	1.001	205521	*1.057*	88.86	**0.803**	156488	**0.805**
no7_ar4_1	92.95	144407	85.81	**0.924**	132259	**0.916**	96.83	1.041	146953	1.018
	128.72	194208	151.26	*1.174*	228478	*1.176*	116.14	**0.903**	171945	**0.885**
	121.89	170770	89.67	**0.738**	133799	**0.784**	162.00	*1.326*	237108	*1.388*
no7_ar5_1	64.06	80824	80.36	*1.251*	103664	*1.282*	60.80	**0.950**	83092	1.028
	71.86	97731	70.46	0.981	96788	0.990	66.80	**0.931**	84633	**0.866**
	65.09	82027	69.19	*1.062*	86135	*1.050*	83.70	*1.282*	109634	*1.336*
nous1	4.84%	4607584	4.96%	1.000	4544557	0.986	4.89%	1.000	4581265	0.994

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	6243.27	3890131	6325.41	1.013	3890131	1.000	6288.08	1.007	3890131	1.000
	2112.65	1607021	2124.11	1.005	1607021	1.000	2123.08	1.005	1607021	1.000
nous2	7.79	7003	7.68	0.987	7003	1.000	7.62	0.981	7003	1.000
	8.64	5591	8.66	1.002	5591	1.000	8.58	0.994	5591	1.000
	5.66	2643	5.59	0.989	2643	1.000	5.70	1.006	2643	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
nuclear10a	∞	93	∞	1.000	94	1.005	∞	1.000	94	1.005
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
nuclear10b	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
nuclear14	∞	5685	∞	1.000	5685	1.000	∞	1.000	5685	1.000
	∞	41571	∞	1.000	41571	1.000	∞	1.000	41571	1.000
	∞	6540	∞	1.000	6540	1.000	∞	1.000	6540	1.000
nuclear14a	$\geq$ 10000%	14103	$\geq$ 10000%	1.000	14262	1.011	$\geq$ 10000%	1.000	14197	1.007
	$\geq$ 10000%	8459	$\geq$ 10000%	1.000	8469	1.001	$\geq$ 10000%	1.000	8469	1.001
	$\geq$ 10000%	11028	$\geq$ 10000%	1.000	10995	0.997	$\geq$ 10000%	1.000	11065	1.003
nuclear14b	87.87%	6969	87.87%	1.000	6038	0.868	87.87%	1.000	5913	0.851
	93.91%	3881	94.11%	1.000	4522	1.161	94.11%	1.000	4522	1.161
	83.97%	5943	83.97%	1.000	5750	0.968	83.97%	1.000	5750	0.968
nuclear25	∞	6119	∞	1.000	6119	1.000	∞	1.000	6119	1.000
	∞	655	∞	1.000	655	1.000	∞	1.000	655	1.000
	∞	23643	∞	1.000	23643	1.000	∞	1.000	23643	1.000
nuclear25a	$\geq$ 10000%	14711	$\geq$ 10000%	1.000	13807	0.939	$\geq$ 10000%	1.000	14683	0.998
	$\geq$ 10000%	4127	$\geq$ 10000%	1.000	4127	1.000	$\geq$ 10000%	1.000	4127	1.000
	∞	5402	$\geq$ 10000%	1.000	9861	1.810	∞	1.000	4768	0.885
nuclear25b	109.05%	6472	114.81%	1.000	4473	0.696	114.81%	1.000	6871	1.061
	106.42%	11009	106.96%	1.000	8700	0.792	106.96%	1.000	8638	0.787
	1045.49%	5158	1028.99%	1.000	7026	1.355	1029.01%	1.000	6973	1.345
nuclear49	∞	17066	∞	1.000	17066	1.000	∞	1.000	17066	1.000
	∞	108412	∞	1.000	108412	1.000	∞	1.000	108412	1.000
	∞	103070	∞	1.000	103070	1.000	∞	1.000	103070	1.000
nuclear49a	∞	4285	∞	1.000	4127	0.964	∞	1.000	4832	1.125

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	3956	∞	1.000	3983	1.007	∞	1.000	3983	1.007
	∞	3185	∞	1.000	3166	0.994	∞	1.000	3215	1.009
nuclear49b	1084.48%	1	1084.48%	1.000	1	1.000	1084.48%	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	1061.39%	1	1061.39%	1.000	1	1.000	1061.39%	1.000	1	1.000
nuclearva	∞	18816	∞	1.000	18816	1.000	∞	1.000	18816	1.000
	∞	6046	∞	1.000	6046	1.000	∞	1.000	6046	1.000
	∞	8666	∞	1.000	8666	1.000	∞	1.000	8666	1.000
nuclearvb	∞	24660	∞	1.000	24660	1.000	∞	1.000	24660	1.000
	∞	2344	∞	1.000	2344	1.000	∞	1.000	2344	1.000
	∞	9956	∞	1.000	9956	1.000	∞	1.000	9956	1.000
nuclearvc	∞	2091	∞	1.000	2091	1.000	∞	1.000	2091	1.000
	∞	943	∞	1.000	943	1.000	∞	1.000	943	1.000
	∞	827	∞	1.000	827	1.000	∞	1.000	827	1.000
nuclearvd	∞	585841	∞	1.000	585841	1.000	∞	1.000	599839	1.024
	∞	420947	∞	1.000	653276	1.552	∞	1.000	1998356	4.746
	∞	1866538	∞	1.000	693317	0.371	∞	1.000	119578	0.064
nuclearve	∞	896895	∞	1.000	1430482	1.595	∞	1.000	493120	0.550
	∞	1568678	∞	1.000	1649144	1.051	∞	1.000	289073	0.184
	∞	772677	∞	1.000	772677	1.000	∞	1.000	354383	0.459
nuclearvf	∞	552062	∞	1.000	444904	0.806	∞	1.000	1940789	3.515
	∞	1237622	∞	1.000	1237622	1.000	∞	1.000	979444	0.791
	∞	715200	∞	1.000	425630	0.595	∞	1.000	1811832	2.533
nvs01	0.50	19	0.50	1.000	19	1.000	0.50	1.000	19	1.000
	0.50	19	0.50	1.000	19	1.000	0.50	1.000	19	1.000
	0.50	19	0.50	1.000	19	1.000	0.50	1.000	19	1.000
nvs02	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs03	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs04	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs05	4.56	646	4.53	0.995	646	1.000	4.52	0.993	646	1.000
	0.63	133	0.58	0.969	133	1.000	0.58	0.969	133	1.000
	6.30	959	6.32	1.003	959	1.000	6.27	0.996	959	1.000
nvs06	0.50	12	0.50	1.000	12	1.000	0.50	1.000	12	1.000
	0.50	12	0.50	1.000	12	1.000	0.50	1.000	12	1.000
	0.50	12	0.50	1.000	12	1.000	0.50	1.000	12	1.000
nvs07	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs08	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
nvs09	2230.28	2753790	2256.47	1.012	2753790	1.000	2246.33	1.007	2753790	1.000
	2234.45	2753790	2233.04	0.999	2753790	1.000	2258.29	1.011	2753790	1.000
	2233.43	2753790	2229.67	0.998	2753790	1.000	2240.83	1.003	2753790	1.000
nvs10	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs11	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs12	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
nvs13	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
nvs14	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs15	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
nvs16	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs17	0.50	44	0.50	1.000	44	1.000	0.50	1.000	43	0.993
	0.50	44	0.50	1.000	44	1.000	0.50	1.000	43	0.993
	0.50	44	0.50	1.000	44	1.000	0.50	1.000	43	0.993
nvs18	0.50	27	0.50	1.000	27	1.000	0.50	1.000	27	1.000
	0.50	39	0.50	1.000	39	1.000	0.50	1.000	35	0.971
	0.50	40	0.50	1.000	40	1.000	0.50	1.000	26	**0.900**
nvs19	0.50	103	0.50	1.000	103	1.000	0.50	1.000	97	0.970
	0.50	109	0.50	1.000	109	1.000	0.50	1.000	101	0.962
	0.50	116	0.50	1.000	116	1.000	0.50	1.000	100	**0.926**
nvs20	1.79	112	1.77	0.993	112	1.000	1.77	0.993	112	1.000
	1.74	118	1.72	0.993	118	1.000	1.80	1.022	118	1.000
nvs21	0.50	30	0.50	1.000	30	1.000	0.50	1.000	30	1.000
	0.50	30	0.50	1.000	30	1.000	0.50	1.000	30	1.000
	0.50	30	0.50	1.000	30	1.000	0.50	1.000	30	1.000
nvs23	0.50	175	0.50	1.000	175	1.000	0.50	1.000	156	**0.931**
	0.59	147	0.57	0.987	147	1.000	0.60	1.006	123	**0.903**
	0.50	163	0.50	1.000	163	1.000	0.50	1.000	137	**0.901**
nvs24	0.58	147	0.57	0.994	149	1.008	0.59	1.006	157	1.040
	0.58	206	0.57	0.994	206	1.000	0.62	1.025	165	**0.866**
	0.77	191	0.74	0.983	191	1.000	0.69	0.955	203	1.041
o7	3650.26	6501371	4120.91	*1.129*	7057473	*1.086*	2987.98	**0.819**	5342403	**0.822**
	3696.48	6280532	1703.89	**0.461**	2998849	**0.477**	1591.38	**0.431**	2696843	**0.429**
	3151.71	5387430	2158.07	**0.685**	3942348	**0.732**	2285.18	**0.725**	4112905	**0.763**
o7_2	957.98	1746312	1035.94	*1.081*	1850193	*1.059*	1173.84	*1.225*	2085189	*1.194*
	1233.69	1995456	1022.45	**0.829**	1799933	**0.902**	920.72	**0.747**	1543138	**0.773**
	723.80	1269425	1012.85	*1.399*	1698053	*1.338*	898.80	*1.241*	1517303	*1.195*
o7_ar25_1	374.05	637130	300.16	**0.803**	498618	**0.783**	242.46	**0.649**	408245	**0.641**
	357.69	598723	363.05	1.015	610953	1.020	252.07	**0.706**	417170	**0.697**
	397.95	698287	303.87	**0.764**	503878	**0.722**	344.45	**0.866**	581506	**0.833**
o7_ar2_1	117.59	205854	75.20	**0.643**	121091	**0.588**	77.38	**0.661**	127615	**0.620**
	128.28	226546	86.12	**0.674**	150189	**0.663**	77.30	**0.606**	128820	**0.569**

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	152.24	253540	83.79	**0.553**	151871	**0.599**	79.39	**0.525**	130518	**0.515**
o7_ar3_1	935.58	1625660	546.10	**0.584**	989759	**0.609**	479.58	**0.513**	855875	**0.527**
	1166.72	2019484	589.75	**0.506**	1060439	**0.525**	588.11	**0.504**	1033184	**0.512**
	591.98	1069256	401.00	**0.678**	714369	**0.668**	460.27	**0.778**	823092	**0.770**
o7_ar4_1	2155.45	3481580	1220.94	**0.567**	2142029	**0.615**	619.99	**0.288**	1072014	**0.308**
	1844.66	3135326	1091.93	**0.592**	1943969	**0.620**	949.68	**0.515**	1658019	**0.529**
	1659.34	2782874	1343.28	**0.810**	2365852	**0.850**	1163.62	**0.701**	1991198	**0.716**
o7_ar5_1	423.08	700674	410.86	0.971	710033	1.013	369.74	**0.874**	598325	**0.854**
	526.97	865099	389.30	**0.739**	615546	**0.712**	409.42	**0.777**	648552	**0.750**
	710.50	1095457	597.86	**0.842**	946413	**0.864**	686.97	0.967	1078849	0.985
o8_ar4_1	4411.54	6706259	4415.30	1.001	6383165	0.952	5121.20	*1.161*	7496062	*1.118*
	6285.83	8616144	5046.12	**0.803**	7403562	**0.859**	3295.09	**0.524**	4727848	**0.549**
	5463.33	8021477	5571.90	1.020	8163735	1.018	3880.78	**0.710**	5749409	**0.717**
o9_ar4_1	4717.44	6655360	6718.99	*1.424*	8775025	*1.318*	7.03%	1.526	9256637	1.391
	25.70%	6966391	7.93%	1.000	9527566	1.368	9.65%	1.000	9341042	1.341
	30.12%	6402740	20.84%	1.000	6905822	1.079	19.23%	1.000	7530210	1.176
oaer	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
oil2	5.85	2	5.91	1.009	2	1.000	5.82	0.996	2	1.000
	8.52	2	8.57	1.005	2	1.000	8.56	1.004	2	1.000
	9.15	2	9.29	1.014	2	1.000	9.16	1.001	2	1.000
oil	38.43%	126920	38.43%	1.000	119131	0.939	38.43%	1.000	127017	1.001
ortez	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
pb302035	511.80%	2965	511.80%	1.000	2993	1.009	511.80%	1.000	2985	1.007
	515.07%	3151	515.07%	1.000	3164	1.004	515.07%	1.000	3155	1.001
	510.17%	2978	509.64%	1.000	2995	1.006	510.17%	1.000	2982	1.001
pb302055	451.64%	3299	451.31%	1.000	3313	1.004	453.42%	1.000	3282	0.995
	481.32%	3132	481.32%	1.000	3147	1.005	481.32%	1.000	3131	1.000
	444.71%	3631	444.86%	1.000	3679	1.013	445.46%	1.000	3670	1.010
pb302075	418.14%	3686	407.09%	1.000	3589	0.974	419.92%	1.000	3477	0.945
	387.51%	3528	387.20%	1.000	3601	1.020	396.36%	1.000	3650	1.034

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	401.73%	3641	411.28%	1.000	3562	0.979	385.95%	1.000	3611	0.992
pb302095	122.73%	7823	113.70%	1.000	7455	0.954	115.59%	1.000	6815	0.873
	112.81%	7699	123.78%	1.000	8441	1.095	120.56%	1.000	8231	1.068
	120.77%	6045	117.50%	1.000	9185	1.511	111.97%	1.000	8055	1.327
pb351535	326.42%	3729	330.07%	1.000	3830	1.026	330.07%	1.000	3828	1.026
	394.91%	3185	394.91%	1.000	3200	1.005	394.91%	1.000	3186	1.000
	335.95%	3691	335.68%	1.000	3698	1.002	335.68%	1.000	3681	0.997
pb351555	322.06%	3594	322.00%	1.000	3627	1.009	321.92%	1.000	3639	1.012
	345.21%	3470	345.12%	1.000	3480	1.003	345.12%	1.000	3471	1.000
	349.45%	3418	349.45%	1.000	3428	1.003	349.45%	1.000	3418	1.000
pb351575	391.15%	3891	388.19%	1.000	3664	0.943	393.17%	1.000	3484	0.898
	387.64%	3504	386.05%	1.000	3542	1.011	393.38%	1.000	3431	0.980
	411.37%	3361	403.95%	1.000	3246	0.967	406.90%	1.000	3349	0.997
pb351595	376.09%	3482	380.85%	1.000	3829	1.097	361.92%	1.000	3681	1.056
	357.62%	2888	343.91%	1.000	3626	1.247	348.79%	1.000	3538	1.218
	391.36%	3508	402.37%	1.000	3762	1.070	358.30%	1.000	3407	0.972
pedigree_ex1058	1347.50	175244	996.50	**0.740**	162858	**0.929**	1445.15	*1.072*	174879	0.998
	627.29	116498	1553.09	*2.474*	189543	*1.626*	1074.92	*1.712*	162024	*1.390*
	1630.08	230650	1082.91	**0.665**	172303	**0.747**	1979.98	*1.215*	232095	1.006
pedigree_ex485	189.72	50947	200.59	*1.057*	56107	*1.101*	202.68	*1.068*	55618	*1.092*
	151.64	34260	171.11	*1.128*	40188	*1.173*	165.19	*1.089*	32482	**0.948**
	215.07	62883	353.12	*1.639*	103966	*1.652*	251.25	*1.167*	67620	*1.075*
pedigree_ex485_2	18.70	7609	28.44	*1.494*	11905	*1.557*	20.37	*1.085*	6793	**0.894**
	9.87	3163	11.41	*1.142*	4044	*1.270*	11.32	*1.133*	4053	*1.273*
	10.01	4034	11.16	*1.104*	4837	*1.194*	11.19	*1.107*	4965	*1.225*
pedigree_sim2000	3.91%	57138	2.62%	1.000	237957	4.159	2.62%	1.000	238068	4.161
	5.41%	58071	4.73%	1.000	59972	1.033	4.73%	1.000	59101	1.018
	2.18%	214770	3.76%	1.000	51160	0.239	4.00%	1.000	51360	0.239
pedigree_sim400	2.31%	1451061	2.16%	1.000	1984175	1.367	2.16%	1.000	1981890	1.366
	2.33%	1642100	2.15%	1.000	1760534	1.072	2.15%	1.000	1759826	1.072
	2.34%	1882378	1.91%	1.000	1768741	0.940	1.91%	1.000	1757619	0.934
pedigree_sp_top4_250	534.28	160235	550.61	1.031	134602	**0.840**	493.07	**0.923**	145692	**0.909**
	675.76	196918	655.20	0.970	191431	0.972	588.58	**0.871**	162579	**0.826**
	801.85	182745	742.96	**0.927**	217466	*1.190*	729.14	**0.909**	201487	*1.103*

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
pedigree_sp_top4_300	546.68	126874	605.23	*1.107*	178361	*1.405*	798.35	*1.460*	148010	*1.166*
	1369.99	289904	669.70	**0.489**	239516	**0.826**	765.33	**0.559**	252628	**0.871**
	1025.30	155124	1144.03	*1.116*	238171	*1.535*	1198.39	*1.169*	198405	*1.279*
pedigree_sp_top4_350tr	1285.83	320255	1398.45	*1.088*	370221	*1.156*	1548.85	*1.204*	449298	*1.403*
	1076.35	529979	963.40	**0.895**	299299	**0.565**	967.92	**0.899**	299299	**0.565**
	2718.11	433771	2357.61	**0.867**	429844	0.991	2043.09	**0.752**	415741	0.958
pedigree_sp_top5_200	1298.17	268863	1878.64	*1.447*	260889	0.970	1121.17	**0.864**	210920	**0.785**
	1296.13	255422	1362.68	*1.051*	242325	**0.949**	1985.96	*1.532*	376410	*1.473*
	1809.82	268037	1804.37	0.997	321092	*1.198*	1434.14	**0.793**	249012	**0.929**
pedigree_sp_top5_250	1997.95	208304	1521.63	**0.762**	218318	1.048	1093.05	**0.547**	205141	0.985
	961.67	183106	1680.49	*1.747*	256593	*1.401*	1754.16	*1.823*	265479	*1.450*
	1541.60	215353	839.28	**0.545**	175151	**0.813**	868.20	**0.563**	193579	**0.899**
pooling_epa1	0.05%	750134	0.05%	1.000	751017	1.001	0.05%	1.000	772411	1.030
	2745.43	799561	2749.71	1.002	799561	1.000	2742.84	0.999	799561	1.000
pooling_epa2	∞	192161	∞	1.000	192166	1.000	∞	1.000	191201	0.995
	∞	253391	∞	1.000	254294	1.004	∞	1.000	254744	1.005
	∞	312227	∞	1.000	312298	1.000	∞	1.000	311937	0.999
pooling_epa3	∞	44450	∞	1.000	44714	1.006	∞	1.000	44588	1.003
	∞	50690	∞	1.000	50993	1.006	∞	1.000	50627	0.999
	∞	45636	∞	1.000	45834	1.004	∞	1.000	45402	0.995
portfol_buyin	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	57.38	20410	44.97	**0.787**	14343	**0.704**	51.62	**0.901**	14862	**0.729**
	41.65	14797	34.70	**0.837**	10967	**0.743**	37.58	**0.905**	10964	**0.743**
	69.53	25751	53.11	**0.767**	17014	**0.662**	51.10	**0.739**	16301	**0.634**
portfol_classical200_2	16.16%	253322	16.95%	1.000	250576	0.989	15.75%	1.000	245083	0.967
	14.56%	261749	15.50%	1.000	259395	0.991	14.62%	1.000	249268	0.952
	14.50%	261326	14.53%	1.000	257237	0.984	15.52%	1.000	247049	0.945
portfol_robust050_34	3.12	60	3.77	*1.158*	40	**0.875**	3.56	*1.107*	74	*1.087*
	2.03	34	2.05	1.007	28	0.955	2.83	*1.264*	28	0.955
	2.78	54	2.75	0.992	40	**0.909**	2.11	**0.823**	35	**0.877**
portfol_robust100_09	23.09	450	18.86	**0.824**	364	**0.844**	20.20	**0.880**	355	**0.827**
	24.13	329	18.61	**0.780**	241	**0.795**	19.87	**0.830**	269	**0.860**
	29.37	624	22.23	**0.765**	406	**0.699**	23.00	**0.790**	389	**0.675**
portfol_robust200_03	3.77%	44864	3.26%	1.000	42663	0.951	3.15%	1.000	39995	0.892

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	3.70%	40109	4.09%	1.000	36195	0.903	3.40%	1.000	38048	0.949
	4.23%	41321	3.86%	1.000	41864	1.013	4.76%	1.000	38582	0.934
portfol_shortfall050_68	13.50	130	13.73	1.016	142	*1.052*	13.62	1.008	159	*1.126*
	7.04	153	6.82	0.973	121	**0.874**	9.41	*1.295*	287	*1.530*
	14.02	86	14.10	1.005	128	*1.226*	14.76	1.049	145	*1.317*
portfol_shortfall100_04	1337.22	56148	1476.03	*1.104*	58960	1.050	1322.82	0.989	49794	**0.887**
	1236.61	52046	1192.64	0.964	50035	0.961	1224.22	0.990	51721	0.994
	1297.55	51112	1223.42	**0.943**	49101	0.961	1206.07	**0.930**	49765	0.974
portfol_shortfall200_05	1.51%	72762	1.44%	1.000	79741	1.096	1.45%	1.000	84594	1.162
	1.51%	73572	1.46%	1.000	78329	1.065	1.39%	1.000	76716	1.043
	1.27%	76652	1.53%	1.000	74639	0.974	1.38%	1.000	74990	0.978
primary	∞	1935201	∞	1.000	1306205	0.675	∞	1.000	1431623	0.740
prob02	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
prob03	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
procsel	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
procurement1large	372.91%	48481	372.91%	1.000	48790	1.006	372.91%	1.000	48579	1.002
	372.73%	51856	372.73%	1.000	52365	1.010	372.73%	1.000	52064	1.004
	370.00%	51558	369.99%	1.000	51730	1.003	370.00%	1.000	51504	0.999
procurement1mot	506.98%	744243	507.01%	1.000	743381	0.999	507.01%	1.000	743433	0.999
	488.93%	856715	489.10%	1.000	853166	0.996	489.14%	1.000	851893	0.994
	531.09%	628706	531.14%	1.000	628324	0.999	531.09%	1.000	628585	1.000
procurement2mot	1.82	48	1.93	1.039	49	1.007	1.96	1.050	49	1.007
	2.39	83	2.39	1.000	85	1.011	2.33	0.982	85	1.011
	3.62	62	3.68	1.013	55	0.957	3.64	1.004	55	0.957
product2	10.31	2	9.84	0.958	2	1.000	9.39	**0.919**	2	1.000
	3.87	1	4.32	*1.092*	1	1.000	4.11	1.049	1	1.000
	8.66	23	15.12	*1.669*	412	*4.163*	9.53	*1.090*	2	**0.829**
product	43.38	2651	38.31	**0.886**	2741	1.033	44.46	1.024	1351	**0.527**

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	50.94	6940	38.60	**0.762**	5521	**0.798**	51.63	1.013	4191	**0.610**
qap	≥ 10000%	263789	≥ 10000%	1.000	251037	0.952	≥ 10000%	1.000	248605	0.942
	∞	288231	≥ 10000%	1.000	284368	0.987	∞	1.000	244357	0.848
	≥ 10000%	267458	≥ 10000%	1.000	275205	1.029	∞	1.000	237599	0.888
qapw	51.16%	44553	51.23%	1.000	46490	1.043	48.54%	1.000	46084	1.034
	51.70%	50105	50.87%	1.000	44017	0.879	51.66%	1.000	48943	0.977
	51.09%	52901	50.90%	1.000	46480	0.879	50.85%	1.000	59156	1.118
qspp_0_10_0_1_10_1	66.13	23727	64.15	0.971	24234	1.021	60.03	**0.909**	23248	0.980
	65.91	27117	60.96	**0.926**	20609	**0.761**	52.47	**0.799**	19657	**0.726**
	72.47	26268	71.64	0.989	25163	0.958	63.99	**0.885**	26207	0.998
qspp_0_11_0_1_10_1	200.24	100851	198.53	0.992	100299	0.995	174.56	**0.872**	96205	0.954
	204.62	97827	192.32	**0.940**	98135	1.003	181.04	**0.885**	92041	**0.941**
	213.22	113147	216.25	1.014	114198	1.009	206.43	0.968	108453	0.959
qspp_0_12_0_1_10_1	568.79	303843	553.67	0.973	307484	1.012	563.78	0.991	310298	1.021
	642.24	325402	602.56	**0.938**	307189	**0.944**	535.04	**0.833**	303981	**0.934**
	639.32	321478	652.32	1.020	349468	*1.087*	574.90	**0.899**	316954	0.986
qspp_0_13_0_1_10_1	3050.48	1343163	2813.67	**0.922**	1226154	**0.913**	2970.96	0.974	1335841	0.995
	3156.21	1352649	2681.75	**0.850**	1211531	**0.896**	2614.64	**0.828**	1249544	**0.924**
	3247.11	1395696	2997.08	**0.923**	1285183	**0.921**	2719.39	**0.838**	1247117	**0.894**
qspp_0_14_0_1_10_1	42.79%	2583477	39.02%	1.000	2558333	0.990	31.67%	1.000	3096830	1.199
	44.88%	2528727	49.84%	1.000	2327179	0.920	49.09%	1.000	2641447	1.045
	51.82%	2402465	46.14%	1.000	2582529	1.075	36.38%	1.000	3036363	1.264
qspp_0_15_0_1_10_1	76.94%	1766570	78.80%	1.000	1649099	0.934	63.86%	1.000	2288752	1.296
	98.05%	1622191	102.86%	1.000	1595634	0.984	91.24%	1.000	1924016	1.186
	97.07%	1622614	92.99%	1.000	1580764	0.974	72.93%	1.000	2049725	1.263
radar-2000-10-a-6_lat_7	82.37	7	83.00	1.008	7	1.000	82.57	1.002	7	1.000
	85.77	7	85.74	1.000	7	1.000	85.49	0.997	7	1.000
	85.51	7	85.83	1.004	7	1.000	85.34	0.998	7	1.000
radar-3000-10-a-8_lat_7	170.86%	19098	170.86%	1.000	18842	0.987	170.86%	1.000	21927	1.147
	170.86%	18389	170.86%	1.000	17880	0.972	170.86%	1.000	20323	1.105
	170.86%	16732	170.86%	1.000	17057	1.019	170.86%	1.000	20484	1.223
ravempb	5.00	8	4.93	0.988	8	1.000	4.98	0.997	8	1.000
	5.35	8	5.35	1.000	8	1.000	5.40	1.008	8	1.000
	4.80	10	4.69	0.981	10	1.000	4.72	0.986	10	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
ringpack_10_1	3.95%	5047393	3.95%	1.000	4715737	0.934	8.22%	1.000	4354224	0.863
	3.95%	6193694	8.22%	1.000	4791308	0.774	3.95%	1.000	3723333	0.601
	3.95%	4996021	3.95%	1.000	4431001	0.887	8.22%	1.000	3582335	0.717
ringpack_10_2	8.22%	3868170	3.95%	1.000	4397974	1.137	3.95%	1.000	3658193	0.946
	3.95%	1884066	8.22%	1.000	3323338	1.764	3.95%	1.000	3874654	2.056
	3.94%	4430920	3.95%	1.000	3641814	0.822	3.95%	1.000	3489514	0.788
ringpack_20_1	278.77%	1425726	278.77%	1.000	1198112	0.840	53.86%	1.000	990688	0.695
	36.44%	1504388	278.77%	1.000	1202768	0.800	35.20%	1.000	1050493	0.698
	218.46%	1238706	65.79%	1.000	1067014	0.861	218.46%	1.000	1042324	0.841
ringpack_20_2	73.38%	1162827	73.38%	1.000	1103359	0.949	73.33%	1.000	955667	0.822
	36.12%	1023677	20.78%	1.000	1009034	0.986	19.75%	1.000	806006	0.787
	52.55%	908141	25.14%	1.000	871006	0.959	60.09%	1.000	885929	0.976
ringpack_20_3	400.00%	1214098	134.76%	1.000	1175524	0.968	17.09%	1.000	986939	0.813
	56.53%	1026964	400.00%	1.000	1079497	1.051	12.35%	1.000	982574	0.957
	400.00%	1098973	12.35%	1.000	1058230	0.963	400.00%	1.000	1196218	1.088
ringpack_30_1	351.78%	345994	351.78%	1.000	345428	0.998	351.78%	1.000	310376	0.897
	379.18%	383460	379.18%	1.000	358521	0.935	379.18%	1.000	290507	0.758
	379.18%	350649	379.18%	1.000	319144	0.910	379.18%	1.000	302874	0.864
ringpack_30_2	223.95%	325360	223.95%	1.000	315041	0.968	191.18%	1.000	320025	0.984
	222.48%	133153	321.17%	1.000	119579	0.898	275.70%	1.000	125647	0.944
	313.18%	378044	263.16%	1.000	378345	1.001	313.18%	1.000	340630	0.901
risk2bpb	1.43	1	1.48	1.021	1	1.000	1.39	0.984	1	1.000
	1.08	1	1.08	1.000	1	1.000	1.09	1.005	1	1.000
	1.03	1	1.01	0.990	1	1.000	1.01	0.990	1	1.000
routingdelay_bigm	139.15	21901	130.11	**0.935**	17286	**0.790**	73.02	**0.528**	10021	**0.460**
	199.69	44013	317.89	*1.589*	81791	*1.856*	72.94	**0.368**	14740	**0.336**
	89.76	13978	84.95	**0.947**	12088	**0.866**	57.25	**0.642**	9921	**0.712**
routingdelay_proj	∞	614404	∞	1.000	615253	1.001	∞	1.000	613213	0.998
	∞	740492	∞	1.000	728979	0.984	∞	1.000	736189	0.994
	∞	736022	∞	1.000	730573	0.993	∞	1.000	727871	0.989
rsyn0805h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
rsyn0805m02h	1.51	3	1.53	1.008	3	1.000	1.50	0.996	3	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1.42	2	1.35	0.971	2	1.000	1.43	1.004	2	1.000
	1.24	2	1.26	1.009	2	1.000	1.23	0.996	2	1.000
rsyn0805m02m	7.43	1525	7.11	0.962	1369	**0.904**	7.12	0.963	1369	**0.904**
	8.51	1595	7.56	**0.900**	1395	**0.882**	7.53	**0.897**	1395	**0.882**
	12.91	4210	9.43	**0.750**	2604	**0.627**	9.42	**0.749**	2604	**0.627**
rsyn0805m03h	1.66	2	1.62	0.985	2	1.000	1.64	0.992	2	1.000
	1.21	2	1.20	0.995	2	1.000	1.19	0.991	2	1.000
	1.12	2	1.13	1.005	2	1.000	1.09	0.986	2	1.000
rsyn0805m03m	17.00	1623	17.25	1.014	2015	*1.228*	17.41	1.023	2015	*1.228*
	10.36	1246	11.26	*1.079*	1402	*1.116*	11.35	*1.087*	1402	*1.116*
	13.85	1748	14.66	*1.055*	1628	**0.935**	14.75	*1.061*	1628	**0.935**
rsyn0805m04h	1.34	2	1.34	1.000	2	1.000	1.34	1.000	2	1.000
	2.69	2	2.65	0.989	2	1.000	2.74	1.014	2	1.000
	2.32	2	2.39	1.021	2	1.000	2.33	1.003	2	1.000
rsyn0805m04m	10.53	824	11.36	*1.072*	1032	*1.225*	11.41	*1.076*	1032	*1.225*
	12.81	1279	14.84	*1.147*	1209	**0.949**	14.98	*1.157*	1209	**0.949**
	7.67	707	8.28	*1.070*	920	*1.264*	8.34	*1.077*	920	*1.264*
rsyn0805m	2.57	106	2.45	0.966	106	1.000	2.41	0.955	106	1.000
	4.76	112	4.73	0.995	102	0.953	4.74	0.997	102	0.953
	1.41	162	1.42	1.004	145	**0.935**	1.38	0.988	145	**0.935**
rsyn0810h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
rsyn0810m02h	2.38	4	2.30	0.976	4	1.000	2.37	0.997	4	1.000
	4.29	24	4.32	1.006	24	1.000	4.32	1.006	24	1.000
	2.10	3	2.08	0.994	3	1.000	2.06	0.987	3	1.000
rsyn0810m02m	9.87	1984	9.63	0.978	1578	**0.805**	9.68	0.983	1578	**0.805**
	9.39	2237	12.33	*1.283*	3201	*1.412*	12.65	*1.314*	3201	*1.412*
	10.26	1926	9.92	0.970	2209	*1.140*	10.06	0.982	2209	*1.140*
rsyn0810m03h	3.67	4	3.69	1.004	4	1.000	3.67	1.000	4	1.000
	4.23	4	4.22	0.998	4	1.000	4.34	1.021	4	1.000
	4.40	4	4.30	0.981	4	1.000	4.35	0.991	4	1.000
rsyn0810m03m	16.99	3434	14.92	**0.885**	2328	**0.687**	15.10	**0.895**	2328	**0.687**
	10.84	1269	11.48	*1.054*	1614	*1.252*	11.51	*1.057*	1614	*1.252*

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	19.87	3286	19.22	0.969	3037	**0.926**	19.29	0.972	3037	**0.926**
rsyn0810m04h	2.46	2	2.44	0.994	2	1.000	2.43	0.991	2	1.000
	3.84	2	3.82	0.996	2	1.000	3.83	0.998	2	1.000
	3.54	2	3.48	0.987	2	1.000	3.45	0.980	2	1.000
rsyn0810m04m	9.08	673	11.23	*1.213*	983	*1.401*	11.24	*1.214*	983	*1.401*
	9.40	646	8.74	**0.937**	629	0.977	8.88	0.950	629	0.977
	12.26	1057	13.62	*1.103*	1402	*1.298*	13.80	*1.116*	1402	*1.298*
rsyn0810m	1.77	52	1.79	1.007	56	1.026	1.73	0.986	56	1.026
	1.77	29	1.73	0.986	29	1.000	1.74	0.989	29	1.000
	1.59	72	1.59	1.000	66	0.965	1.64	1.019	66	0.965
rsyn0815h	1.09	2	1.09	1.000	2	1.000	1.10	1.005	2	1.000
	1.31	4	1.28	0.987	4	1.000	1.27	0.983	4	1.000
	0.62	2	0.61	0.994	2	1.000	0.62	1.000	2	1.000
rsyn0815m02h	2.32	4	2.27	0.985	4	1.000	2.28	0.988	4	1.000
	1.77	2	1.82	1.018	2	1.000	1.84	1.025	2	1.000
	2.12	3	2.03	0.971	3	1.000	2.07	0.984	3	1.000
rsyn0815m02m	4.97	1116	8.72	*1.628*	1504	*1.319*	8.68	*1.621*	1504	*1.319*
	10.41	1579	8.25	**0.811**	1171	**0.757**	8.25	**0.811**	1171	**0.757**
	15.23	3964	10.62	**0.716**	1543	**0.404**	10.82	**0.728**	1543	**0.404**
rsyn0815m03h	5.73	22	5.78	1.007	22	1.000	5.84	1.016	22	1.000
	4.97	54	4.92	0.992	54	1.000	5.00	1.005	54	1.000
	4.87	50	4.85	0.997	50	1.000	4.87	1.000	50	1.000
rsyn0815m03m	17.78	2533	17.30	0.974	2407	0.952	17.26	0.972	2407	0.952
	15.71	1057	16.24	1.032	1349	*1.252*	16.24	1.032	1349	*1.252*
	26.41	3764	27.82	*1.051*	3217	**0.858**	28.15	*1.063*	3217	**0.858**
rsyn0815m04h	5.07	4	5.11	1.007	4	1.000	5.18	1.018	4	1.000
	5.05	3	5.18	1.021	3	1.000	5.17	1.020	3	1.000
	3.13	2	3.05	0.981	2	1.000	3.09	0.990	2	1.000
rsyn0815m04m	31.58	4068	30.26	0.959	3742	**0.922**	30.58	0.969	3742	**0.922**
	30.43	2654	31.31	1.028	2396	**0.906**	31.64	1.038	2396	**0.906**
	34.28	3469	39.31	*1.143*	3762	*1.082*	39.49	*1.148*	3762	*1.082*
rsyn0815m	1.74	46	1.72	0.993	50	1.027	1.75	1.004	50	1.027
	0.81	122	0.84	1.017	128	1.027	0.84	1.017	128	1.027
	1.02	53	1.01	0.995	51	0.987	1.01	0.995	57	1.026

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
rsyn0820h	2.31	5	2.25	0.982	5	1.000	2.28	0.991	5	1.000
	1.75	2	1.79	1.015	2	1.000	1.78	1.011	2	1.000
	1.88	3	1.81	0.976	3	1.000	1.84	0.986	3	1.000
rsyn0820m02h	2.88	7	2.86	0.995	7	1.000	2.80	0.979	7	1.000
	3.15	4	3.15	1.000	4	1.000	3.20	1.012	4	1.000
	2.78	3	2.82	1.011	3	1.000	2.80	1.005	3	1.000
rsyn0820m02m	8.44	1552	10.29	*1.196*	1860	*1.186*	10.38	*1.206*	1860	*1.186*
	9.57	884	9.93	1.034	838	0.953	10.07	1.047	838	0.953
	10.18	1761	13.21	*1.271*	1973	*1.114*	13.31	*1.280*	1973	*1.114*
rsyn0820m03h	4.55	3	4.62	1.013	3	1.000	4.58	1.005	3	1.000
	5.18	2	5.09	0.985	2	1.000	5.22	1.006	2	1.000
	5.63	54	5.67	1.006	54	1.000	5.77	1.021	54	1.000
rsyn0820m03m	12.77	1993	12.02	**0.946**	1583	**0.804**	12.07	**0.949**	1583	**0.804**
	14.72	1928	17.36	*1.168*	2091	*1.080*	17.52	*1.178*	2091	*1.080*
	14.08	1518	12.62	**0.903**	1178	**0.790**	12.83	**0.917**	1178	**0.790**
rsyn0820m04h	7.39	5	7.49	1.012	5	1.000	7.42	1.004	5	1.000
	5.95	31	5.86	0.987	31	1.000	5.87	0.988	31	1.000
	2.97	2	2.95	0.995	2	1.000	2.94	0.992	2	1.000
rsyn0820m04m	54.42	7313	49.03	**0.903**	6450	**0.884**	49.54	**0.912**	6450	**0.884**
	47.03	5836	43.00	**0.916**	4879	**0.839**	43.32	**0.923**	4879	**0.839**
	50.71	6715	57.08	*1.123*	8520	*1.265*	57.47	*1.131*	8520	*1.265*
rsyn0820m	1.53	107	1.52	0.996	120	*1.063*	1.53	1.000	120	*1.063*
	1.22	200	1.19	0.986	183	**0.943**	1.19	0.986	183	**0.943**
	1.47	143	1.47	1.000	156	*1.053*	1.50	1.012	156	*1.053*
rsyn0830h	4.21	29	4.17	0.992	29	1.000	4.15	0.988	29	1.000
	2.81	37	2.83	1.005	37	1.000	2.82	1.003	37	1.000
	2.64	35	2.59	0.986	35	1.000	2.64	1.000	35	1.000
rsyn0830m02h	9.38	12	9.22	0.985	10	0.982	9.26	0.988	10	0.982
	4.81	51	4.83	1.003	51	1.000	4.83	1.003	51	1.000
	8.72	10	8.70	0.998	10	1.000	8.78	1.006	10	1.000
rsyn0830m02m	11.20	1331	10.01	**0.902**	1169	**0.887**	10.17	**0.916**	1169	**0.887**
	9.82	1199	13.21	*1.313*	2321	*1.864*	13.38	*1.329*	2321	*1.864*
	7.72	391	7.25	**0.946**	577	*1.379*	7.39	0.962	577	*1.379*
rsyn0830m03h	8.47	10	8.43	0.996	10	1.000	8.44	0.997	10	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	11.71	33	11.70	0.999	33	1.000	11.51	0.984	33	1.000
	10.19	10	10.06	0.988	10	1.000	10.16	0.997	10	1.000
rsyn0830m03m	22.92	2380	21.05	**0.922**	2205	**0.929**	21.12	**0.925**	2205	**0.929**
	20.93	2077	26.43	*1.251*	2692	*1.282*	26.51	*1.254*	2692	*1.282*
	25.59	3098	23.46	**0.920**	1929	**0.634**	23.61	**0.926**	1929	**0.634**
rsyn0830m04h	11.61	67	11.61	1.000	67	1.000	11.79	1.014	67	1.000
	14.58	63	14.51	0.996	63	1.000	14.55	0.998	63	1.000
	18.28	64	18.12	0.992	64	1.000	18.33	1.003	64	1.000
rsyn0830m04m	54.36	5196	51.75	0.953	6466	*1.240*	52.05	0.958	6466	*1.240*
	89.85	9648	69.69	**0.778**	7370	**0.766**	70.45	**0.786**	7370	**0.766**
	66.06	8293	57.90	**0.878**	4770	**0.580**	58.65	**0.890**	4770	**0.580**
rsyn0830m	1.13	116	1.07	0.972	110	0.972	1.08	0.977	110	0.972
	1.57	55	1.59	1.008	63	*1.052*	1.57	1.000	63	*1.052*
	1.02	84	1.15	*1.064*	102	*1.098*	1.13	*1.054*	102	*1.098*
rsyn0840h	0.98	3	0.97	0.995	3	1.000	1.01	1.015	3	1.000
	0.89	3	0.92	1.016	3	1.000	0.90	1.005	3	1.000
	1.09	18	1.09	1.000	18	1.000	1.10	1.005	18	1.000
rsyn0840m02h	3.02	4	3.03	1.002	4	1.000	2.94	0.980	4	1.000
	2.78	2	2.81	1.008	2	1.000	2.82	1.011	2	1.000
	5.25	6	5.26	1.002	6	1.000	5.28	1.005	6	1.000
rsyn0840m02m	13.17	1250	13.50	1.023	1138	**0.917**	13.49	1.023	1138	**0.917**
	10.59	703	12.27	*1.145*	853	*1.187*	12.43	*1.159*	853	*1.187*
	13.18	917	12.99	0.987	1017	*1.098*	13.14	0.997	1017	*1.098*
rsyn0840m03h	12.36	27	12.20	0.988	27	1.000	12.23	0.990	27	1.000
	11.08	80	11.10	1.002	80	1.000	11.12	1.003	80	1.000
	13.61	18	13.47	0.990	18	1.000	13.54	0.995	18	1.000
rsyn0840m03m	13.94	640	17.12	*1.213*	1096	*1.616*	17.46	*1.236*	1096	*1.616*
	14.47	693	14.83	1.023	569	**0.844**	14.80	1.021	569	**0.844**
	16.49	551	17.04	1.031	683	*1.203*	17.16	1.038	683	*1.203*
rsyn0840m04h	15.62	763	15.60	0.999	762	0.999	15.58	0.998	757	0.993
	17.42	377	17.47	1.003	377	1.000	17.43	1.001	377	1.000
rsyn0840m04m	78.17	11161	80.67	1.032	10504	**0.942**	81.46	1.042	10504	**0.942**
	99.32	13156	54.87	**0.557**	5690	**0.437**	55.45	**0.563**	5690	**0.437**
	109.63	10762	91.03	**0.832**	6327	**0.592**	92.22	**0.843**	6327	**0.592**

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
rsyn0840m	1.90	153	1.45	**0.845**	152	0.996	1.44	**0.841**	152	0.996
	1.16	90	1.34	*1.083*	136	*1.242*	1.35	*1.088*	136	*1.242*
	1.75	172	1.64	0.960	147	**0.908**	1.67	0.971	147	**0.908**
saa_2	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
sepasequ_complex	54.21%	2728633	74.44%	1.000	2276185	0.834	44.72%	1.000	1214702	0.445
	38.30%	1737508	21.90%	1.000	365572	0.210	28.71%	1.000	493509	0.284
	22.54%	366183	34.95%	1.000	573356	1.566	14.78%	1.000	243252	0.664
sepasequ_convent	20.60	1022	20.36	0.989	1022	1.000	20.64	1.002	1022	1.000
	27.24	587	26.92	0.989	587	1.000	27.13	0.996	587	1.000
	30.66	1993	30.10	0.982	1993	1.000	30.31	0.989	1993	1.000
sfacloc1_2_80	85.82%	2435884	88.44%	1.000	2595606	1.066	81.78%	1.000	2104867	0.864
	45.34%	3031838	45.17%	1.000	3059554	1.009	45.31%	1.000	3035153	1.001
	86.73%	4133185	86.62%	1.000	4149495	1.004	86.64%	1.000	4145916	1.003
sfacloc1_2_90	54.45%	910187	54.38%	1.000	912438	1.002	54.41%	1.000	911322	1.001
	38.27%	3598354	38.25%	1.000	3616069	1.005	38.07%	1.000	3561406	0.990
	18.35%	8228726	18.37%	1.000	8201417	0.997	18.25%	1.000	8346239	1.014
sfacloc1_2_95	0.66%	9744003	0.76%	1.000	9441763	0.969	0.60%	1.000	9518196	0.977
	0.91%	9118300	5.50%	1.000	8002547	0.878	5.23%	1.000	7902974	0.867
	4.17%	8159494	3.97%	1.000	8201619	1.005	3.11%	1.000	8481413	1.039
sfacloc1_3_80	3765.08%	1555698	3765.08%	1.000	1568312	1.008	3765.08%	1.000	1558194	1.002
	1549.44%	1508448	1543.62%	1.000	1525325	1.011	1549.44%	1.000	1508515	1.000
	3615.89%	1689363	3589.32%	1.000	1701997	1.007	3607.35%	1.000	1695082	1.003
sfacloc1_3_90	364.51%	2601782	363.36%	1.000	2619564	1.007	364.51%	1.000	2601685	1.000
sfacloc1_3_95	60.32%	3662613	60.14%	1.000	3699014	1.010	60.61%	1.000	3334989	0.911
	898.50%	2167023	871.11%	1.000	2171941	1.002	871.15%	1.000	2149906	0.992
	929.88%	2067202	1025.67%	1.000	2086708	1.009	933.81%	1.000	2044696	0.989
sfacloc2_2_80	8.11	1076	7.98	0.986	1076	1.000	8.04	0.992	1076	1.000
	6.41	1224	6.22	0.974	1224	1.000	6.38	0.996	1224	1.000
	6.98	845	6.92	0.992	845	1.000	6.99	1.001	845	1.000
sfacloc2_2_90	1.65	510	1.70	1.019	510	1.000	1.68	1.011	510	1.000
	1.35	295	1.37	1.009	295	1.000	1.36	1.004	295	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
sfacloc2_2_95	1.41	198	1.38	0.988	198	1.000	1.37	0.983	198	1.000
	0.99	170	1.00	1.005	170	1.000	0.96	0.985	170	1.000
	1.31	256	1.31	1.000	256	1.000	1.33	1.009	256	1.000
sfacloc2_3_80	33.30	8993	33.06	0.993	8993	1.000	33.24	0.998	8987	0.999
	22.27	6804	22.12	0.994	6804	1.000	22.20	0.997	6794	0.999
	25.80	5731	25.87	1.003	5731	1.000	26.31	1.019	5713	0.997
sfacloc2_3_90	8.02	2539	7.91	0.988	2539	1.000	8.02	1.000	2539	1.000
	10.23	3721	10.30	1.006	3721	1.000	10.18	0.996	3721	1.000
	6.81	2471	6.73	0.990	2471	1.000	6.71	0.987	2471	1.000
sfacloc2_3_95	7.08	2004	7.17	1.011	2004	1.000	5.99	**0.865**	1889	**0.945**
	3.56	1265	3.54	0.996	1265	1.000	3.56	1.000	1265	1.000
	2.90	1289	2.87	0.992	1289	1.000	2.95	1.013	1289	1.000
sfacloc2_4_80	51.78	21451	57.49	*1.108*	24769	*1.154*	54.26	1.047	22954	*1.070*
	59.04	27845	67.58	*1.142*	31919	*1.146*	44.27	**0.754**	17847	**0.642**
sfacloc2_4_90	10.89	3040	11.24	1.029	3267	*1.072*	10.37	0.956	3138	1.031
	12.84	4264	11.46	**0.900**	3664	**0.863**	12.74	0.993	3869	**0.909**
	12.67	4092	13.02	1.026	4788	*1.166*	11.08	**0.884**	2809	**0.694**
sfacloc2_4_95	6.82	2827	5.49	**0.830**	2118	**0.758**	6.70	0.985	2782	0.985
	6.33	3369	5.56	**0.895**	2311	**0.695**	5.11	**0.834**	2100	**0.634**
	5.45	3235	5.56	1.017	3078	0.953	6.10	*1.101*	2939	**0.911**
sjup2	2.44%	1	2.44%	1.000	1	1.000	2.44%	1.000	1	1.000
	2.63%	1	2.63%	1.000	1	1.000	2.63%	1.000	1	1.000
	2.63%	1	2.63%	1.000	1	1.000	2.63%	1.000	1	1.000
slay04h	1.44	33	1.43	0.996	33	1.000	1.47	1.012	32	0.992
	2.23	17	2.24	1.003	17	1.000	2.22	0.997	17	1.000
	6.35	14	6.28	0.990	14	1.000	6.33	0.997	14	1.000
slay04m	3.20	8	3.18	0.995	8	1.000	3.23	1.007	8	1.000
	3.78	12	3.77	0.998	12	1.000	3.81	1.006	12	1.000
	2.73	10	2.70	0.992	10	1.000	2.70	0.992	10	1.000
slay05h	2.73	136	3.18	*1.121*	165	*1.123*	3.26	*1.142*	169	*1.140*
	2.00	51	2.08	1.027	49	0.987	2.08	1.027	48	0.980
	2.54	101	2.59	1.014	96	0.975	2.29	**0.929**	85	**0.920**
slay05m	1.45	14	1.43	0.992	14	1.000	1.41	0.984	14	1.000
	1.17	12	1.18	1.005	12	1.000	1.23	1.028	14	1.018

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1.61	12	1.67	1.023	12	1.000	1.67	1.023	12	1.000
slay06h	12.27	37	12.26	0.999	30	**0.949**	12.35	1.006	29	**0.942**
	4.83	251	4.54	0.950	197	**0.846**	3.78	**0.820**	163	**0.749**
	15.01	39	14.92	0.994	33	0.957	14.89	0.993	33	0.957
slay06m	3.35	30	3.28	0.984	26	0.969	3.33	0.995	29	0.992
	4.27	22	4.20	0.987	22	1.000	4.22	0.991	22	1.000
	3.48	18	3.40	0.982	14	0.966	3.45	0.993	14	0.966
slay07h	13.61	502	13.99	1.026	470	**0.947**	13.34	0.982	467	**0.942**
	14.44	548	14.40	0.997	441	**0.835**	15.17	1.047	430	**0.818**
	14.13	708	14.19	1.004	680	0.965	12.53	**0.894**	543	**0.796**
slay07m	2.35	55	2.43	1.024	43	**0.923**	2.49	1.042	44	**0.929**
	2.27	55	2.27	1.000	49	0.961	2.03	**0.927**	46	**0.942**
	2.21	51	2.21	1.000	54	1.020	2.24	1.009	51	1.000
slay08h	23.91	1103	21.74	**0.913**	1222	*1.099*	21.04	**0.885**	1114	1.009
	27.36	1428	27.08	0.990	1538	*1.072*	27.46	1.004	1510	*1.054*
	20.29	1046	22.40	*1.099*	927	**0.896**	19.86	0.980	806	**0.791**
slay08m	3.13	65	2.76	**0.910**	56	**0.945**	2.82	**0.925**	55	**0.939**
	3.53	123	3.49	0.991	128	1.022	3.55	1.004	124	1.004
	2.37	71	2.34	0.991	74	1.018	2.41	1.012	68	0.982
slay09h	49.60	4350	53.38	*1.075*	4565	1.048	50.61	1.020	4076	**0.938**
	34.57	1666	34.22	0.990	1415	**0.858**	44.87	*1.290*	1321	**0.805**
	45.73	2894	69.76	*1.514*	2909	1.005	71.31	*1.547*	2422	**0.842**
slay09m	4.68	141	5.05	*1.065*	148	1.029	4.67	0.998	161	*1.083*
	4.13	168	4.15	1.004	116	**0.806**	4.13	1.000	130	**0.858**
	4.72	123	5.10	*1.066*	105	**0.919**	5.13	*1.072*	103	**0.910**
slay10h	304.04	52296	302.27	0.994	52087	0.996	199.52	**0.657**	25019	**0.479**
	509.09	111289	291.50	**0.573**	44456	**0.400**	341.74	**0.672**	63189	**0.568**
	270.22	41205	262.26	0.971	35175	**0.854**	178.01	**0.660**	19345	**0.471**
slay10m	22.62	1760	20.76	**0.921**	1878	*1.063*	21.46	0.951	1748	0.994
	19.53	1997	19.13	0.981	1570	**0.796**	19.63	1.005	1738	**0.876**
	28.43	2001	25.51	**0.901**	2348	*1.165*	27.48	0.968	2025	1.011
smallinvDAXr1b010-011	0.50	102	0.50	1.000	120	*1.089*	0.50	1.000	100	0.990
	0.50	102	0.50	1.000	120	*1.089*	0.50	1.000	100	0.990
	0.50	102	0.50	1.000	120	*1.089*	0.50	1.000	100	0.990

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
smallinvDAXr1b020-022	0.50	76	0.50	1.000	76	1.000	0.50	1.000	86	*1.057*
	0.50	76	0.50	1.000	76	1.000	0.50	1.000	86	*1.057*
	0.50	76	0.50	1.000	76	1.000	0.50	1.000	86	*1.057*
smallinvDAXr1b050-055	0.50	292	0.50	1.000	326	*1.087*	0.50	1.000	259	**0.916**
	0.50	292	0.50	1.000	326	*1.087*	0.50	1.000	259	**0.916**
	0.50	292	0.50	1.000	326	*1.087*	0.50	1.000	259	**0.916**
smallinvDAXr1b100-110	0.50	408	0.55	1.033	562	*1.303*	0.73	*1.153*	686	*1.547*
	0.50	408	0.54	1.027	562	*1.303*	0.69	*1.127*	686	*1.547*
	0.50	408	0.53	1.020	562	*1.303*	0.71	*1.140*	686	*1.547*
smallinvDAXr1b150-165	0.68	812	0.98	*1.179*	1012	*1.219*	0.71	1.018	766	**0.950**
	0.71	812	0.96	*1.146*	1012	*1.219*	0.74	1.018	766	**0.950**
	0.73	812	0.94	*1.121*	1012	*1.219*	0.71	0.988	766	**0.950**
smallinvDAXr1b200-220	0.50	202	0.58	*1.053*	332	*1.430*	0.63	*1.087*	462	*1.861*
	0.50	202	0.57	1.047	332	*1.430*	0.62	*1.080*	462	*1.861*
	0.52	202	0.60	*1.053*	332	*1.430*	0.61	*1.059*	462	*1.861*
smallinvDAXr2b010-011	0.50	90	0.50	1.000	78	**0.937**	0.50	1.000	88	0.989
	0.50	90	0.50	1.000	78	**0.937**	0.50	1.000	88	0.989
	0.50	90	0.50	1.000	78	**0.937**	0.50	1.000	88	0.989
smallinvDAXr2b020-022	0.50	94	0.50	1.000	136	*1.216*	0.50	1.000	114	*1.103*
	0.50	94	0.50	1.000	136	*1.216*	0.50	1.000	114	*1.103*
	0.50	94	0.50	1.000	136	*1.216*	0.50	1.000	114	*1.103*
smallinvDAXr2b050-055	0.50	191	0.50	1.000	228	*1.127*	0.50	1.000	278	*1.299*
	0.50	191	0.50	1.000	228	*1.127*	0.50	1.000	278	*1.299*
	0.50	191	0.50	1.000	228	*1.127*	0.50	1.000	278	*1.299*
smallinvDAXr2b100-110	0.50	315	0.69	*1.127*	567	*1.607*	0.57	1.047	551	*1.569*
	0.50	315	0.72	*1.147*	567	*1.607*	0.57	1.047	551	*1.569*
	0.50	315	0.69	*1.127*	567	*1.607*	0.60	*1.067*	551	*1.569*
smallinvDAXr2b150-165	0.57	552	0.77	*1.127*	914	*1.555*	0.72	*1.096*	812	*1.399*
	0.59	552	0.80	*1.132*	914	*1.555*	0.75	*1.101*	812	*1.399*
	0.61	552	0.74	*1.081*	914	*1.555*	0.72	*1.068*	812	*1.399*
smallinvDAXr2b200-220	0.61	480	0.93	*1.199*	1178	*2.203*	0.71	*1.062*	733	*1.436*
	0.66	480	0.93	*1.163*	1178	*2.203*	0.74	1.048	733	*1.436*
	0.62	480	0.89	*1.167*	1178	*2.203*	0.69	1.043	733	*1.436*
smallinvDAXr3b010-011	0.50	101	0.50	1.000	106	1.025	0.50	1.000	90	**0.945**

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	101	0.50	1.000	106	1.025	0.50	1.000	90	**0.945**
	0.50	101	0.50	1.000	106	1.025	0.50	1.000	90	**0.945**
smallinvDAXr3b020-022	0.50	110	0.50	1.000	138	*1.133*	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	138	*1.133*	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	138	*1.133*	0.50	1.000	115	1.024
smallinvDAXr3b050-055	0.50	130	0.50	1.000	207	*1.335*	0.50	1.000	167	*1.161*
	0.50	130	0.50	1.000	207	*1.335*	0.50	1.000	167	*1.161*
	0.50	130	0.50	1.000	207	*1.335*	0.50	1.000	167	*1.161*
smallinvDAXr3b100-110	0.50	322	0.67	*1.113*	692	*1.877*	0.55	1.033	496	*1.412*
	0.50	322	0.70	*1.133*	692	*1.877*	0.55	1.033	496	*1.412*
	0.50	322	0.70	*1.133*	692	*1.877*	0.59	*1.060*	496	*1.412*
smallinvDAXr3b150-165	0.61	518	0.79	*1.112*	914	*1.641*	0.63	1.012	682	*1.265*
	0.58	518	0.75	*1.108*	914	*1.641*	0.65	1.044	682	*1.265*
	0.64	518	0.76	*1.073*	914	*1.641*	0.61	0.982	682	*1.265*
smallinvDAXr3b200-220	0.57	380	0.66	*1.057*	348	**0.933**	0.71	*1.089*	470	*1.188*
	0.61	380	0.61	1.000	348	**0.933**	0.70	*1.056*	470	*1.188*
	0.62	380	0.62	1.000	348	**0.933**	0.70	1.049	470	*1.188*
smallinvDAXr4b010-011	0.50	101	0.50	1.000	106	1.025	0.50	1.000	90	**0.945**
	0.50	101	0.50	1.000	106	1.025	0.50	1.000	90	**0.945**
	0.50	101	0.50	1.000	106	1.025	0.50	1.000	90	**0.945**
smallinvDAXr4b020-022	0.50	110	0.50	1.000	136	*1.124*	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	136	*1.124*	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	136	*1.124*	0.50	1.000	115	1.024
smallinvDAXr4b050-055	0.50	132	0.50	1.000	205	*1.315*	0.50	1.000	168	*1.155*
	0.50	132	0.50	1.000	205	*1.315*	0.50	1.000	168	*1.155*
	0.50	132	0.50	1.000	205	*1.315*	0.50	1.000	168	*1.155*
smallinvDAXr4b100-110	0.50	331	0.71	*1.140*	692	*1.838*	0.66	*1.107*	532	*1.466*
	0.50	331	0.68	*1.120*	692	*1.838*	0.66	*1.107*	532	*1.466*
	0.50	331	0.70	*1.133*	692	*1.838*	0.59	*1.060*	532	*1.466*
smallinvDAXr4b150-165	0.57	562	0.79	*1.140*	914	*1.532*	0.65	*1.051*	682	*1.181*
	0.57	562	0.78	*1.134*	914	*1.532*	0.67	*1.064*	682	*1.181*
	0.59	562	0.79	*1.126*	914	*1.532*	0.64	1.031	682	*1.181*
smallinvDAXr4b200-220	0.60	380	0.62	1.012	348	**0.933**	0.69	*1.056*	470	*1.188*
	0.59	380	0.64	1.031	348	**0.933**	0.70	*1.069*	470	*1.188*

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.62	380	0.65	1.019	348	**0.933**	0.67	1.031	470	*1.188*
smallinvDAXr5b010-011	0.50	148	0.50	1.000	114	**0.863**	0.50	1.000	88	**0.758**
	0.50	148	0.50	1.000	114	**0.863**	0.50	1.000	88	**0.758**
	0.50	148	0.50	1.000	114	**0.863**	0.50	1.000	88	**0.758**
smallinvDAXr5b020-022	0.50	110	0.50	1.000	136	*1.124*	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	136	*1.124*	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	136	*1.124*	0.50	1.000	115	1.024
smallinvDAXr5b050-055	0.50	132	0.50	1.000	205	*1.315*	0.50	1.000	168	*1.155*
	0.50	132	0.50	1.000	205	*1.315*	0.50	1.000	168	*1.155*
	0.50	132	0.50	1.000	205	*1.315*	0.50	1.000	168	*1.155*
smallinvDAXr5b100-110	0.50	331	0.67	*1.113*	692	*1.838*	0.65	*1.100*	532	*1.466*
	0.50	331	0.69	*1.127*	692	*1.838*	0.65	*1.100*	532	*1.466*
	0.50	331	0.72	*1.147*	692	*1.838*	0.63	*1.087*	532	*1.466*
smallinvDAXr5b150-165	0.60	562	0.81	*1.131*	914	*1.532*	0.60	1.000	692	*1.196*
	0.59	562	0.76	*1.107*	914	*1.532*	0.62	1.019	692	*1.196*
	0.55	562	0.79	*1.155*	914	*1.532*	0.64	*1.058*	692	*1.196*
smallinvDAXr5b200-220	0.59	380	0.70	*1.069*	348	**0.933**	0.68	*1.057*	470	*1.188*
	0.62	380	0.67	1.031	348	**0.933**	0.74	*1.074*	470	*1.188*
	0.57	380	0.68	*1.070*	348	**0.933**	0.69	*1.076*	470	*1.188*
smallinvSNPr1b010-011	5.76	826	5.97	1.031	881	*1.059*	5.89	1.019	881	*1.059*
	5.67	826	5.85	1.027	881	*1.059*	5.91	1.036	881	*1.059*
	5.63	826	5.83	1.030	881	*1.059*	5.87	1.036	881	*1.059*
smallinvSNPr1b020-022	168.51	52018	230.43	*1.365*	74667	*1.435*	232.61	*1.378*	74667	*1.435*
	169.30	52018	230.87	*1.362*	74667	*1.435*	230.67	*1.360*	74667	*1.435*
	169.00	52018	229.15	*1.354*	74667	*1.435*	231.31	*1.367*	74667	*1.435*
smallinvSNPr1b050-055	4104.98	660385	820.90%	1.754	942157	1.427	819.31%	1.754	945731	1.432
	4096.49	660385	819.31%	1.757	945731	1.432	819.31%	1.757	945731	1.432
	4123.20	660385	819.31%	1.746	945731	1.432	819.18%	1.746	945988	1.432
smallinvSNPr1b100-110	∞	440398	∞	1.000	409930	0.931	∞	1.000	406119	0.922
	∞	438007	∞	1.000	411260	0.939	∞	1.000	405266	0.925
	∞	438543	∞	1.000	411016	0.937	∞	1.000	405564	0.925
smallinvSNPr1b150-165	∞	317018	∞	1.000	305362	0.963	∞	1.000	296624	0.936
	∞	317392	∞	1.000	304328	0.959	∞	1.000	296602	0.935
	∞	318011	∞	1.000	305362	0.960	∞	1.000	296679	0.933

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Table E.1: Detailed computational results on MINLPLIB.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
smallinvSNPr1b200-220	∞	201592	∞	1.000	239698	1.189	∞	1.000	239506	1.188
	∞	202031	∞	1.000	239045	1.183	∞	1.000	239971	1.188
	∞	202539	∞	1.000	239698	1.183	∞	1.000	239698	1.183
smallinvSNPr2b010-011	4.30	498	4.04	0.951	428	**0.883**	4.07	0.957	428	**0.883**
	4.34	498	4.02	**0.940**	428	**0.883**	4.08	0.951	428	**0.883**
	4.30	498	4.05	0.953	428	**0.883**	4.07	0.957	428	**0.883**
smallinvSNPr2b020-022	29.68	7513	44.28	*1.476*	12322	*1.632*	44.25	*1.475*	12322	*1.632*
	29.73	7513	44.36	*1.476*	12322	*1.632*	44.63	*1.485*	12322	*1.632*
	29.84	7513	44.51	*1.476*	12322	*1.632*	44.48	*1.475*	12322	*1.632*
smallinvSNPr2b050-055	393.41	78269	1311.02	*3.327*	237908	*3.037*	1278.81	*3.245*	238093	*3.039*
	394.12	78269	1292.15	*3.273*	237908	*3.037*	1274.61	*3.228*	238093	*3.039*
	394.66	78269	1291.51	*3.267*	237908	*3.037*	1280.49	*3.239*	238093	*3.039*
smallinvSNPr2b100-110	∞	347615	∞	1.000	438355	1.261	∞	1.000	438355	1.261
	∞	346516	∞	1.000	438355	1.265	∞	1.000	437995	1.264
	∞	347449	∞	1.000	439337	1.264	∞	1.000	437995	1.261
smallinvSNPr2b150-165	31.88%	96769	3199.72	**0.444**	123108	*1.272*	3195.18	**0.444**	123108	*1.272*
	31.78%	97510	3194.33	**0.444**	123108	*1.262*	3178.61	**0.442**	123108	*1.262*
	31.86%	96880	3176.16	**0.441**	123108	*1.270*	3195.02	**0.444**	123108	*1.270*
smallinvSNPr2b200-220	69.89%	52496	∞	1.000	246952	4.697	63.02%	1.000	61314	1.168
	70.02%	52341	∞	1.000	247497	4.721	62.99%	1.000	61462	1.174
	69.83%	52676	∞	1.000	248072	4.702	62.93%	1.000	61654	1.170
smallinvSNPr3b010-011	3.87	113	3.92	1.010	139	*1.122*	3.95	1.016	139	*1.122*
	3.85	113	3.86	1.002	139	*1.122*	3.91	1.012	139	*1.122*
	3.92	113	3.90	0.996	139	*1.122*	3.88	0.992	139	*1.122*
smallinvSNPr3b020-022	6.70	564	6.04	**0.914**	377	**0.718**	6.11	**0.923**	377	**0.718**
	6.70	564	6.03	**0.913**	377	**0.718**	6.09	**0.921**	377	**0.718**
	6.80	564	6.04	**0.903**	377	**0.718**	6.11	**0.912**	377	**0.718**
smallinvSNPr3b050-055	78.90	6221	173.92	*2.189*	30996	*4.919*	173.34	*2.182*	30996	*4.919*
	78.77	6221	173.57	*2.188*	30996	*4.919*	173.69	*2.190*	30996	*4.919*
	78.75	6221	173.61	*2.189*	30996	*4.919*	174.52	*2.201*	30996	*4.919*
smallinvSNPr3b100-110	126.62	3962	426.17	*3.347*	24382	*6.027*	424.60	*3.335*	24382	*6.027*
	126.55	3962	426.38	*3.351*	24382	*6.027*	426.84	*3.354*	24382	*6.027*
	126.33	3962	425.68	*3.351*	24382	*6.027*	425.51	*3.350*	24382	*6.027*
smallinvSNPr3b150-165	∞	573926	∞	1.000	437120	0.762	∞	1.000	318384	0.555

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	568528	∞	1.000	437120	0.769	∞	1.000	320175	0.563
	∞	569523	∞	1.000	437120	0.768	∞	1.000	318573	0.559
smallinvSNPr3b200-220	∞	560586	∞	1.000	469146	0.837	∞	1.000	469525	0.838
	∞	561649	∞	1.000	470140	0.837	∞	1.000	469312	0.836
	∞	561095	∞	1.000	469525	0.837	∞	1.000	469742	0.837
smallinvSNPr4b010-011	3.38	191	3.46	1.018	214	*1.079*	3.45	1.016	214	*1.079*
	3.35	191	3.43	1.018	214	*1.079*	3.40	1.011	214	*1.079*
	3.39	191	3.43	1.009	214	*1.079*	3.50	1.025	214	*1.079*
smallinvSNPr4b020-022	8.64	333	7.03	**0.833**	272	**0.859**	7.13	**0.843**	272	**0.859**
	8.77	333	7.12	**0.831**	272	**0.859**	7.10	**0.829**	272	**0.859**
	8.80	333	7.12	**0.829**	272	**0.859**	7.10	**0.827**	272	**0.859**
smallinvSNPr4b050-055	22.16	1998	23.37	*1.052*	2471	*1.225*	23.39	*1.053*	2471	*1.225*
	22.33	1998	23.35	1.044	2471	*1.225*	23.52	*1.051*	2471	*1.225*
	22.13	1998	23.36	*1.053*	2471	*1.225*	23.44	*1.057*	2471	*1.225*
smallinvSNPr4b100-110	126.03	8139	129.24	1.025	6901	**0.850**	128.44	1.019	7040	**0.867**
	126.79	8139	130.45	1.029	6901	**0.850**	128.05	1.010	7040	**0.867**
	126.58	8139	130.07	1.027	6901	**0.850**	127.99	1.011	7040	**0.867**
smallinvSNPr4b150-165	155.34	4688	211.43	*1.359*	5672	*1.206*	224.64	*1.443*	6391	*1.356*
	155.11	4688	211.51	*1.361*	5672	*1.206*	224.21	*1.443*	6391	*1.356*
	155.96	4688	211.96	*1.357*	5672	*1.206*	225.16	*1.441*	6391	*1.356*
smallinvSNPr4b200-220	389.93	30337	2790.62	*7.141*	188033	*6.181*	3073.46	*7.864*	223360	*7.342*
	385.59	30337	2800.00	*7.245*	188033	*6.181*	3041.85	*7.871*	223360	*7.342*
	386.97	30337	2785.86	*7.183*	188033	*6.181*	3049.26	*7.862*	223360	*7.342*
smallinvSNPr5b010-011	1.99	87	1.98	0.997	99	*1.064*	2.00	1.003	99	*1.064*
	2.02	87	2.01	0.997	99	*1.064*	2.02	1.000	99	*1.064*
	1.99	87	2.00	1.003	99	*1.064*	1.99	1.000	99	*1.064*
smallinvSNPr5b020-022	4.57	89	4.16	**0.926**	88	0.995	4.15	**0.925**	88	0.995
	4.58	89	4.12	**0.918**	88	0.995	4.17	**0.927**	88	0.995
	4.58	89	4.16	**0.925**	88	0.995	4.13	**0.919**	88	0.995
smallinvSNPr5b050-055	32.88	554	14.54	**0.459**	235	**0.512**	14.27	**0.451**	229	**0.503**
	33.17	554	14.44	**0.452**	235	**0.512**	14.10	**0.442**	229	**0.503**
	33.02	554	14.59	**0.458**	235	**0.512**	14.18	**0.446**	229	**0.503**
smallinvSNPr5b100-110	39.55	758	50.02	*1.258*	1662	*2.054*	50.05	*1.259*	1662	*2.054*
	39.54	758	50.32	*1.266*	1662	*2.054*	50.43	*1.269*	1662	*2.054*

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	39.65	758	50.11	*1.257*	1662	*2.054*	50.21	*1.260*	1662	*2.054*
smallinvSNPr5b150-165	103.40	4693	92.79	**0.898**	4675	0.996	92.70	**0.898**	4675	0.996
	104.58	4693	91.83	**0.879**	4675	0.996	92.46	**0.885**	4675	0.996
	104.54	4693	92.09	**0.882**	4675	0.996	92.49	**0.886**	4675	0.996
smallinvSNPr5b200-220	613.12	37721	1837.80	*2.994*	119598	*3.165*	1906.62	*3.106*	116700	*3.088*
	615.52	37721	1842.99	*2.991*	119598	*3.165*	1894.21	*3.074*	116700	*3.088*
	612.15	37721	1837.70	*2.999*	119598	*3.165*	1902.05	*3.104*	116700	*3.088*
sonet17v4	956.75	6401	824.08	**0.861**	5703	**0.893**	813.46	**0.850**	5703	**0.893**
	1133.93	6947	1152.79	1.017	6947	1.000	1138.76	1.004	6947	1.000
	1227.93	8187	1247.51	1.016	8187	1.000	1229.42	1.001	8187	1.000
sonet18v6	1028.31	4755	1136.07	*1.105*	5604	*1.175*	984.95	0.958	4489	**0.945**
	1112.88	4969	1091.21	0.981	4815	0.970	1076.64	0.967	4815	0.970
	1298.14	7123	1338.91	1.031	7389	1.037	1239.29	0.955	6327	**0.890**
sonet19v5	8.74%	30740	8.90%	1.000	30393	0.989	7164.64	0.995	30475	0.991
	6521.83	26431	7110.55	*1.090*	27027	1.022	7002.25	*1.074*	26919	1.018
	6936.58	27697	7031.54	1.014	27161	0.981	10.80%	1.038	30059	1.085
sonet20v6	2533.89	3937	2239.48	**0.884**	3100	**0.793**	2358.04	**0.931**	3214	**0.821**
	1926.22	2477	1948.74	1.012	2450	0.990	2206.94	*1.146*	3060	*1.226*
	1703.92	2454	1748.65	1.026	2464	1.004	1730.33	1.015	2538	1.033
sonet21v6	5.44%	20003	5.25%	1.000	20819	1.041	5.24%	1.000	21281	1.064
	5.38%	20654	5.24%	1.000	22147	1.072	5.23%	1.000	22370	1.083
	5.11%	27944	5.23%	1.000	24053	0.861	5.23%	1.000	24124	0.864
sonet22v4	7.02%	15275	6.38%	1.000	16713	1.094	6.38%	1.000	16670	1.091
	7.36%	11771	6.95%	1.000	11676	0.992	6.93%	1.000	11824	1.004
	6.87%	16366	7.17%	1.000	14158	0.866	7.17%	1.000	14141	0.865
sonet22v5	192.03%	2465	218.12%	1.000	2483	1.007	174.58%	1.000	2498	1.013
	210.42%	2709	234.44%	1.000	2706	0.999	167.02%	1.000	2408	0.893
	213.94%	2195	201.33%	1.000	1974	0.904	201.02%	1.000	2252	1.025
	91.07%	3909	101.26%	1.000	3855	0.987	102.00%	1.000	4853	1.235
sonet23v6	20.26%	4660	21.00%	1.000	2995	0.650	25.98%	1.000	1673	0.372
	18.49%	8134	20.98%	1.000	7562	0.931	19.67%	1.000	8732	1.073
	20.02%	8300	19.99%	1.000	8324	1.003	20.11%	1.000	8691	1.047
sonet24v2	384.74	91	394.87	1.026	91	1.000	388.66	1.010	91	1.000
	151.05	26	155.64	1.030	26	1.000	152.15	1.007	26	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	307.92	63	312.40	1.015	63	1.000	307.99	1.000	63	1.000
sonet24v5	204.66%	1172	162.06%	1.000	1134	0.970	217.43%	1.000	1155	0.987
	218.74%	1554	197.20%	1.000	1604	1.030	199.50%	1.000	1481	0.956
	191.32%	1288	204.52%	1.000	1387	1.071	236.86%	1.000	1408	1.086
sonet25v5	11.04%	5574	9.63%	1.000	4215	0.760	9.62%	1.000	4322	0.779
	10.58%	3533	10.65%	1.000	2814	0.802	10.65%	1.000	2975	0.846
	10.74%	5828	11.11%	1.000	6095	1.045	11.10%	1.000	6156	1.055
sonet25v6	287.81%	710	339.40%	1.000	822	1.138	360.91%	1.000	784	1.091
	331.63%	843	358.46%	1.000	857	1.015	317.34%	1.000	878	1.037
	329.58%	927	333.32%	1.000	933	1.006	369.19%	1.000	958	1.030
sonetgr17	86.28%	115239	88.07%	1.000	119315	1.035	88.94%	1.000	121341	1.053
	100.46%	128372	95.05%	1.000	139117	1.084	93.82%	1.000	137501	1.071
	96.35%	125420	108.97%	1.000	114871	0.916	90.98%	1.000	145527	1.160
space25	∞	299	∞	1.000	4931	12.609	∞	1.000	5128	13.103
	∞	590	∞	1.000	339	0.636	∞	1.000	96	0.284
	∞	6649	∞	1.000	9620	1.440	∞	1.000	813	0.135
space25a	∞	975	∞	1.000	1549	1.534	∞	1.000	2131	2.075
	∞	850	∞	1.000	961	1.117	∞	1.000	1098	1.261
	∞	1419	∞	1.000	565	0.438	∞	1.000	411	0.336
space960	∞	1681	∞	1.000	1679	0.999	∞	1.000	1720	1.022
	∞	1830	∞	1.000	1901	1.037	∞	1.000	2098	1.139
	∞	1409	∞	1.000	1569	1.106	∞	1.000	1513	1.069
spectra2	7.94	16	7.91	0.997	16	1.000	7.99	1.006	16	1.000
	8.15	16	8.19	1.004	16	1.000	8.22	1.008	16	1.000
	9.04	14	9.04	1.000	14	1.000	9.05	1.001	14	1.000
sporttournament06	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
sporttournament08	0.83	119	0.82	0.995	121	1.009	0.84	1.005	147	*1.128*
	0.81	119	0.81	1.000	121	1.009	0.85	1.022	147	*1.128*
	0.84	119	0.80	0.978	121	1.009	0.85	1.005	147	*1.128*
sporttournament10	2.06	582	1.97	0.971	479	**0.849**	2.03	0.990	511	**0.896**
	2.05	582	1.94	0.964	479	**0.849**	2.02	0.990	511	**0.896**
	2.06	582	1.97	0.971	479	**0.849**	2.07	1.003	511	**0.896**

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
sporttournament12	6.39	868	6.02	**0.950**	904	1.037	6.27	0.984	995	*1.131*
	6.31	868	6.01	0.959	904	1.037	6.32	1.001	995	*1.131*
	6.30	868	6.08	0.970	904	1.037	6.25	0.993	995	*1.131*
sporttournament14	6.59%	45151	6.59%	1.000	45148	1.000	6.60%	1.000	44923	0.995
	6.59%	45104	6.59%	1.000	45097	1.000	6.59%	1.000	45125	1.000
	6.59%	45113	6.59%	1.000	45082	0.999	6.59%	1.000	45111	1.000
sporttournament16	51.50	4785	37.62	**0.736**	4018	**0.843**	36.47	**0.714**	3958	**0.831**
	51.36	4785	37.78	**0.741**	4018	**0.843**	36.52	**0.717**	3958	**0.831**
	51.50	4785	37.69	**0.737**	4018	**0.843**	36.37	**0.712**	3958	**0.831**
sporttournament18	510.88	137834	407.53	**0.798**	87604	**0.636**	518.27	1.014	135577	0.984
	511.38	137834	407.26	**0.797**	87604	**0.636**	518.27	1.013	135577	0.984
	511.04	137834	406.99	**0.797**	87604	**0.636**	518.14	1.014	135577	0.984
sporttournament20	2.17%	2351103	1.74%	1.000	2164885	0.921	6466.71	**0.898**	1813679	**0.771**
	2.17%	2348794	1.73%	1.000	2169138	0.924	6479.30	**0.900**	1813679	**0.772**
	2.17%	2347432	1.74%	1.000	2166576	0.923	6456.04	**0.897**	1813679	**0.773**
sporttournament22	5.32%	1537654	5.61%	1.000	1511368	0.983	5.68%	1.000	1536902	1.000
	5.63%	1440663	5.61%	1.000	1512202	1.050	5.68%	1.000	1542278	1.071
	5.48%	1951952	5.55%	1.000	1661789	0.851	5.81%	1.000	1701963	0.872
sporttournament24	5.40%	862891	5.83%	1.000	814481	0.944	5.40%	1.000	816160	0.946
	5.40%	858321	5.83%	1.000	816928	0.952	5.41%	1.000	812317	0.946
	5.40%	863017	5.83%	1.000	814497	0.944	5.41%	1.000	812471	0.941
sporttournament26	10.75%	608618	10.71%	1.000	392624	0.645	10.28%	1.000	367025	0.603
	10.75%	606985	11.24%	1.000	459568	0.757	10.12%	1.000	346294	0.571
	10.75%	476331	11.38%	1.000	471705	0.990	10.19%	1.000	388254	0.815
sporttournament28	9.23%	321005	9.05%	1.000	168720	0.526	7.87%	1.000	236471	0.737
	9.23%	319591	9.03%	1.000	178316	0.558	7.87%	1.000	236311	0.739
	12.58%	153540	9.27%	1.000	284632	1.853	9.39%	1.000	256372	1.669
sporttournament30	17.17%	68994	16.34%	1.000	101851	1.476	18.52%	1.000	576993	8.352
	17.17%	69052	16.34%	1.000	102151	1.479	18.56%	1.000	566631	8.195
	17.17%	68963	16.34%	1.000	102055	1.479	18.60%	1.000	536866	7.775
sporttournament32	19.66%	30001	20.08%	1.000	366004	12.163	18.67%	1.000	348061	11.566
	17.62%	340411	17.61%	1.000	274886	0.808	16.73%	1.000	265114	0.779
	19.90%	30138	18.39%	1.000	363324	12.019	18.52%	1.000	326464	10.800
sporttournament34	21.11%	356789	20.33%	1.000	249702	0.700	20.68%	1.000	273716	0.767

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	21.11%	356934	19.43%	1.000	258633	0.725	21.19%	1.000	251792	0.706
	21.11%	356064	19.80%	1.000	245573	0.690	20.68%	1.000	273895	0.769
sporttournament36	19.21%	152553	20.97%	1.000	155125	1.017	20.71%	1.000	166374	1.091
	21.18%	178601	20.04%	1.000	136873	0.766	20.70%	1.000	166926	0.935
	19.74%	153285	20.23%	1.000	149525	0.975	19.64%	1.000	163185	1.065
sporttournament38	23.18%	102614	24.05%	1.000	72158	0.703	25.05%	1.000	80197	0.782
	23.67%	93218	24.05%	1.000	71442	0.767	25.04%	1.000	80371	0.862
	22.91%	90508	24.83%	1.000	73098	0.808	25.03%	1.000	80987	0.895
sporttournament40	25.33%	79631	25.68%	1.000	76271	0.958	27.94%	1.000	98245	1.233
	26.12%	73557	24.94%	1.000	73191	0.995	26.72%	1.000	76119	1.035
	27.42%	43930	25.64%	1.000	101321	2.303	26.70%	1.000	95859	2.179
sporttournament42	25.07%	64991	24.91%	1.000	78573	1.209	24.29%	1.000	82659	1.271
	25.09%	82718	25.57%	1.000	77457	0.936	24.39%	1.000	36689	0.444
	24.27%	71148	24.13%	1.000	62459	0.878	23.66%	1.000	78708	1.106
sporttournament44	30.57%	76561	29.99%	1.000	76111	0.994	27.74%	1.000	67324	0.880
	30.25%	65687	29.42%	1.000	77461	1.179	27.44%	1.000	69041	1.051
	30.60%	74416	30.00%	1.000	75822	1.019	28.31%	1.000	73058	0.982
sporttournament46	28.20%	56660	28.80%	1.000	54076	0.954	29.43%	1.000	61351	1.083
	28.73%	75611	27.80%	1.000	51158	0.677	28.40%	1.000	59984	0.794
	28.41%	29622	26.66%	1.000	29026	0.980	25.66%	1.000	29232	0.987
sporttournament48	28.07%	46021	28.01%	1.000	36671	0.797	27.97%	1.000	41242	0.896
	26.70%	20130	27.81%	1.000	53201	2.635	28.21%	1.000	58612	2.902
	27.16%	40615	28.21%	1.000	46128	1.135	27.84%	1.000	45226	1.113
sporttournament50	32.68%	48557	31.68%	1.000	44028	0.907	30.90%	1.000	44422	0.915
	31.80%	46384	30.80%	1.000	29385	0.634	29.84%	1.000	62138	1.339
	30.54%	54639	31.33%	1.000	48119	0.881	31.52%	1.000	49577	0.908
spring	0.50	34	0.50	1.000	34	1.000	0.50	1.000	34	1.000
	0.50	34	0.50	1.000	34	1.000	0.50	1.000	34	1.000
	0.50	34	0.50	1.000	34	1.000	0.50	1.000	34	1.000
squfl010-025	447.81	333	452.51	1.010	333	1.000	128.70	**0.289**	319	0.968
	129.87	317	140.83	*1.084*	327	1.024	125.75	0.969	307	0.976
	479.67	319	477.76	0.996	319	1.000	160.58	**0.336**	303	0.962
squfl010-040	48.66%	63	48.66%	1.000	63	1.000	79.04%	1.000	47	0.902
	78.47%	39	78.47%	1.000	39	1.000	52.55%	1.000	43	1.029

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	96.93%	28	96.93%	1.000	28	1.000	77.58%	1.000	36	1.062
squfl010-040persp	5.93	1	5.77	0.977	1	1.000	5.83	0.986	1	1.000
	5.93	1	5.76	0.975	1	1.000	5.84	0.987	1	1.000
	6.14	1	5.79	0.951	1	1.000	5.98	0.978	1	1.000
squfl010-080	104.65%	64	104.65%	1.000	64	1.000	104.65%	1.000	64	1.000
	147.22%	47	147.22%	1.000	47	1.000	147.22%	1.000	47	1.000
	120.36%	52	120.36%	1.000	52	1.000	120.36%	1.000	52	1.000
squfl015-060	68.31%	219	68.17%	1.000	228	1.028	77.14%	1.000	137	0.743
	82.77%	172	82.77%	1.000	166	0.978	85.22%	1.000	156	0.941
	87.75%	175	82.19%	1.000	189	1.051	82.91%	1.000	152	0.916
squfl015-080	117.21%	81	117.21%	1.000	81	1.000	117.21%	1.000	96	1.083
	122.52%	68	122.52%	1.000	69	1.006	110.57%	1.000	96	1.167
	118.90%	91	131.40%	1.000	70	0.890	123.43%	1.000	82	0.953
squfl020-040	125.09%	111	125.09%	1.000	111	1.000	109.47%	1.000	162	1.242
	65.98%	139	48.60%	1.000	254	1.481	75.30%	1.000	145	1.025
	75.33%	159	75.33%	1.000	164	1.019	93.30%	1.000	138	0.919
squfl020-050	163.59%	155	163.59%	1.000	155	1.000	163.34%	1.000	147	0.969
	105.06%	167	105.71%	1.000	179	1.045	102.76%	1.000	177	1.037
	103.67%	189	99.40%	1.000	203	1.048	114.50%	1.000	98	0.685
squfl020-150	286.08%	1	286.08%	1.000	1	1.000	286.08%	1.000	1	1.000
	284.20%	1	284.20%	1.000	1	1.000	284.20%	1.000	1	1.000
	438.58%	1	435.01%	1.000	1	1.000	438.71%	1.000	1	1.000
squfl025-025	4461.31	5081	5369.39	*1.203*	5308	1.044	5234.78	*1.173*	5175	1.018
	4604.72	5427	5034.62	*1.093*	5630	1.037	4258.81	**0.925**	4436	**0.821**
squfl025-030	33.01%	2849	34.32%	1.000	2298	0.813	20.46%	1.000	2554	0.900
	36.91%	2491	56.58%	1.000	1289	0.536	23.40%	1.000	3267	1.299
	35.20%	2272	32.58%	1.000	2754	1.203	17.20%	1.000	3157	1.373
squfl025-040	110.13%	569	112.64%	1.000	465	0.845	119.63%	1.000	480	0.867
	126.03%	758	122.90%	1.000	804	1.054	134.09%	1.000	483	0.679
	112.79%	595	120.91%	1.000	456	0.800	144.29%	1.000	290	0.561
squfl030-100	261.20%	5	261.20%	1.000	6	1.010	261.20%	1.000	5	1.000
	257.69%	3	257.69%	1.000	5	1.019	257.69%	1.000	3	1.000
	261.22%	5	261.22%	1.000	7	1.019	261.22%	1.000	5	1.000
squfl030-150	615.85%	1	608.13%	1.000	1	1.000	615.85%	1.000	1	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	610.50%	1	602.85%	1.000	1	1.000	610.50%	1.000	1	1.000
	578.71%	1	571.77%	1.000	1	1.000	578.44%	1.000	1	1.000
squfl040-080	263.46%	6	263.46%	1.000	6	1.000	263.46%	1.000	6	1.000
	414.56%	8	414.56%	1.000	8	1.000	414.56%	1.000	8	1.000
	273.30%	6	273.30%	1.000	8	1.019	273.30%	1.000	6	1.000
sssd08-04	9.94	18996	10.49	*1.050*	19073	1.004	10.57	*1.058*	19073	1.004
	10.84	21122	10.90	1.005	21508	1.018	10.31	0.955	20728	0.981
	11.52	21722	11.43	0.993	21188	0.976	11.20	0.974	21188	0.976
sssd08-04persp	8.98	16666	9.03	1.005	16666	1.000	9.17	1.019	16666	1.000
	9.40	18506	9.45	1.005	18506	1.000	9.58	1.017	18506	1.000
	9.65	17423	9.64	0.999	17423	1.000	9.90	1.023	17423	1.000
sssd12-05	3.23%	12723887	2.41%	1.000	13460742	1.058	4585.38	**0.637**	9080544	**0.714**
	6279.63	11344673	2.48%	1.147	11378339	1.003	4598.26	**0.732**	8257726	**0.728**
	6292.13	10621401	5553.97	**0.883**	10204982	0.961	4183.60	**0.665**	7850120	**0.739**
sssd12-05persp	2.90%	12707892	2.93%	1.000	12633137	0.994	2.90%	1.000	12688561	0.998
	3.53%	11804394	3.62%	1.000	11458589	0.971	3.58%	1.000	11751271	0.995
	3.62%	12382303	3.67%	1.000	12186661	0.984	3.65%	1.000	12270685	0.991
sssd15-04	9.62%	4699876	9.62%	1.000	4596578	0.978	9.63%	1.000	4590638	0.977
	9.80%	4687665	10.27%	1.000	3491499	0.745	10.27%	1.000	3476300	0.742
	9.12%	6271631	9.54%	1.000	4700095	0.749	9.54%	1.000	4700095	0.749
sssd15-04persp	9.66%	4660267	9.66%	1.000	4645283	0.997	9.66%	1.000	4655885	0.999
	9.60%	3246577	9.61%	1.000	3228657	0.994	9.61%	1.000	3228657	0.994
	10.34%	4429787	10.35%	1.000	4426111	0.999	10.34%	1.000	4449143	1.004
sssd15-06	21.15%	4882716	21.99%	1.000	4118338	0.843	20.19%	1.000	5162082	1.057
	19.64%	5315021	20.17%	1.000	5000047	0.941	19.60%	1.000	5273476	0.992
	20.66%	3782018	21.10%	1.000	3427137	0.906	20.00%	1.000	4057915	1.073
sssd15-06persp	19.77%	3514660	19.94%	1.000	3753536	1.068	19.46%	1.000	4632572	1.318
	19.62%	3829182	19.45%	1.000	3857478	1.007	18.89%	1.000	5383925	1.406
	19.53%	3865144	19.18%	1.000	3965778	1.026	19.96%	1.000	3776371	0.977
sssd15-08	17.05%	6021881	17.08%	1.000	7164473	1.190	16.45%	1.000	7784970	1.293
	17.10%	6780030	17.00%	1.000	6887442	1.016	16.67%	1.000	7429088	1.096
	17.02%	6688263	16.93%	1.000	7575259	1.133	16.39%	1.000	7571929	1.132
sssd15-08persp	16.91%	5080567	16.72%	1.000	4930441	0.970	16.72%	1.000	4926481	0.970
	16.59%	4877459	16.27%	1.000	5015948	1.028	16.27%	1.000	5023372	1.030

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	16.27%	4802730	16.40%	1.000	4927826	1.026	16.27%	1.000	4930711	1.027
sssd16-07	16.34%	4928361	16.10%	1.000	5716050	1.160	15.96%	1.000	5425514	1.101
	16.46%	4969603	16.56%	1.000	4986753	1.003	15.91%	1.000	5683511	1.144
	16.24%	5174249	16.25%	1.000	5121490	0.990	15.85%	1.000	5330357	1.030
sssd16-07persp	16.29%	3280317	16.31%	1.000	3198766	0.975	16.30%	1.000	3267544	0.996
	15.81%	4131779	15.94%	1.000	4095683	0.991	15.94%	1.000	4117293	0.996
	16.30%	4262899	16.30%	1.000	4300292	1.009	16.30%	1.000	4300106	1.009
sssd18-06	16.19%	2980222	16.18%	1.000	3091336	1.037	16.26%	1.000	3248189	1.090
	16.40%	3608497	16.39%	1.000	3550580	0.984	15.75%	1.000	3120211	0.865
	17.05%	3471056	17.03%	1.000	3248367	0.936	16.39%	1.000	3682901	1.061
sssd18-06persp	16.19%	1667473	16.19%	1.000	1670988	1.002	16.19%	1.000	1681005	1.008
	16.08%	1934599	16.08%	1.000	1969851	1.018	16.07%	1.000	1985522	1.026
	16.31%	1882656	16.31%	1.000	1900839	1.010	16.31%	1.000	1894518	1.006
sssd18-08	30.10%	5140728	30.68%	1.000	4677144	0.910	28.65%	1.000	4932274	0.959
	29.15%	5000594	29.14%	1.000	5258631	1.052	27.65%	1.000	5925608	1.185
	29.08%	4855505	29.33%	1.000	4914887	1.012	28.42%	1.000	5939454	1.223
sssd18-08persp	28.56%	3522615	28.21%	1.000	2781376	0.790	28.44%	1.000	2768022	0.786
	28.67%	3256501	28.42%	1.000	3419202	1.050	28.47%	1.000	2721052	0.836
	28.52%	3635479	29.22%	1.000	2733015	0.752	28.40%	1.000	3563832	0.980
sssd20-04	17.70%	2690820	17.64%	1.000	2736260	1.017	17.64%	1.000	2734596	1.016
	18.25%	4005453	18.43%	1.000	3458520	0.863	18.41%	1.000	3320126	0.829
	18.02%	3372152	18.27%	1.000	3510041	1.041	18.28%	1.000	3498028	1.037
sssd20-04persp	16.10%	1383131	16.10%	1.000	1376886	0.995	16.10%	1.000	1383764	1.000
	15.93%	1444610	16.19%	1.000	1428709	0.989	16.21%	1.000	1417868	0.981
	16.41%	1506606	16.41%	1.000	1503333	0.998	16.41%	1.000	1494748	0.992
sssd20-08	17.40%	3830078	17.42%	1.000	4279996	1.117	16.91%	1.000	3851442	1.006
	16.31%	3776591	16.39%	1.000	4352393	1.152	16.46%	1.000	4088987	1.083
	16.88%	3437432	17.20%	1.000	3984850	1.159	16.58%	1.000	3818790	1.111
sssd20-08persp	16.23%	2034117	16.11%	1.000	2279362	1.121	16.25%	1.000	2203728	1.083
	15.87%	2406408	15.87%	1.000	2400759	0.998	15.87%	1.000	2403480	0.999
	16.27%	1944331	15.97%	1.000	2269067	1.167	15.97%	1.000	2267035	1.166
sssd22-08	18.13%	3866790	18.29%	1.000	3810869	0.986	18.34%	1.000	3026969	0.783
	17.28%	3036051	17.26%	1.000	3262202	1.074	17.14%	1.000	3261502	1.074
	17.50%	3472333	17.62%	1.000	3271943	0.942	17.60%	1.000	2885184	0.831

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
sssd22-08persp	17.42%	2033453	17.23%	1.000	2004313	0.986	17.42%	1.000	2027991	0.997
	17.34%	1830194	17.67%	1.000	1785565	0.976	17.67%	1.000	1798917	0.983
	17.27%	1700274	17.48%	1.000	2032054	1.195	17.48%	1.000	2020736	1.188
sssd25-04	23.08%	3471234	23.04%	1.000	4577915	1.319	23.03%	1.000	4640274	1.337
	22.10%	1977139	22.04%	1.000	2382696	1.205	22.04%	1.000	2381072	1.204
	23.32%	2556967	23.29%	1.000	2524849	0.987	23.21%	1.000	2555729	1.000
sssd25-04persp	21.28%	1463300	21.29%	1.000	1455918	0.995	21.29%	1.000	1522558	1.040
	20.95%	1535486	20.98%	1.000	1531526	0.997	20.99%	1.000	1527874	0.995
	21.15%	1544843	21.15%	1.000	1531435	0.991	21.15%	1.000	1542828	0.999
sssd25-08	15.37%	2575266	15.19%	1.000	2674024	1.038	15.03%	1.000	2591507	1.006
	14.87%	2377275	14.91%	1.000	2770866	1.166	14.91%	1.000	2770803	1.166
	15.01%	2647388	14.94%	1.000	2677841	1.012	14.94%	1.000	2524270	0.953
sssd25-08persp	14.58%	1716834	14.58%	1.000	1745938	1.017	14.58%	1.000	1725530	1.005
	14.35%	1810462	14.54%	1.000	1690700	0.934	14.54%	1.000	1674815	0.925
	14.37%	1623602	14.37%	1.000	1625911	1.001	14.38%	1.000	1600393	0.986
st_e13	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_e14	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
st_e15	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_e27	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_e29	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_e31	2.84	575	2.79	0.987	575	1.000	2.76	0.979	575	1.000
	3.04	595	3.10	1.015	595	1.000	3.12	1.020	595	1.000
	2.95	601	3.03	1.020	601	1.000	2.95	1.000	601	1.000
st_e35	21.57	6981	21.71	1.006	6981	1.000	33.61	*1.533*	13043	*1.856*

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
st_e40	0.50	26	0.50	1.000	26	1.000	0.50	1.000	26	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_miqp2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_miqp3	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_miqp4	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_miqp5	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test1	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
st_test2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test3	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test4	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test5	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
st_test6	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test8	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_testgr1	0.50	14	0.50	1.000	14	1.000	0.50	1.000	16	1.018
	0.50	28	0.50	1.000	28	1.000	0.50	1.000	18	**0.922**
	0.50	28	0.50	1.000	28	1.000	0.50	1.000	18	**0.922**
st_testgr3	0.50	4	0.50	1.000	4	1.000	0.50	1.000	4	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_testph4	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
stockcycle	101.88	10397	93.54	**0.919**	10092	0.971	116.51	*1.142*	11605	*1.115*
	94.75	7441	124.81	*1.314*	10263	*1.374*	220.85	*2.317*	16870	*2.250*
	126.58	10920	121.13	0.957	12486	*1.142*	140.64	*1.110*	11728	*1.073*
super3t	57.67%	164	57.67%	1.000	165	1.004	57.67%	1.000	164	1.000
	61.89%	802	61.89%	1.000	802	1.000	61.89%	1.000	802	1.000
	65.07%	150	65.07%	1.000	150	1.000	65.07%	1.000	150	1.000
supplychainp1_020306	0.70	4	0.71	1.006	4	1.000	0.68	0.988	4	1.000
	0.72	5	0.75	1.017	5	1.000	0.72	1.000	5	1.000
	0.67	4	0.66	0.994	4	1.000	0.68	1.006	4	1.000
supplychainp1_022020	345.88	45652	510.07	*1.473*	112880	*2.469*	510.65	*1.475*	112854	*2.469*
	426.80	89871	475.57	*1.114*	90491	1.007	479.31	*1.123*	90491	1.007
	303.51	23315	460.47	*1.515*	46131	*1.974*	465.15	*1.531*	46131	*1.974*
supplychainp1_030510	3.91	1084	3.96	1.010	1084	1.000	3.96	1.010	1084	1.000
	2.94	471	2.07	**0.779**	168	**0.469**	1.96	**0.751**	168	**0.469**
	2.85	758	1.62	**0.681**	142	**0.282**	1.56	**0.665**	142	**0.282**
supplychainp1_053050	47.03%	21024	47.40%	1.000	29210	1.388	47.45%	1.000	28616	1.359
	41.57%	32277	44.28%	1.000	31827	0.986	44.32%	1.000	30961	0.959
	43.76%	33380	38.18%	1.000	34233	1.025	38.24%	1.000	33445	1.002
supplychainr1_020306	1.78	4	1.79	1.004	4	1.000	1.77	0.996	4	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1.65	4	1.66	1.004	4	1.000	1.62	0.989	4	1.000
	2.77	4	2.76	0.997	4	1.000	2.75	0.995	4	1.000
supplychainr1_022020	67.85	10993	68.30	1.007	10993	1.000	68.22	1.005	10993	1.000
	0.35%	7239502	0.35%	1.000	7188783	0.993	0.35%	1.000	7175424	0.991
	0.35%	7592051	0.35%	1.000	7456134	0.982	0.35%	1.000	7487381	0.986
supplychainr1_030510	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
supplychainr1_053050	20.98%	165663	21.22%	1.000	220903	1.333	21.32%	1.000	211100	1.274
	24.24%	235870	27.19%	1.000	134188	0.569	27.23%	1.000	132353	0.561
	25.79%	108023	19.58%	1.000	248924	2.303	19.69%	1.000	237900	2.201
syn05h	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn05m02h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn05m02m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn05m03h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn05m03m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn05m04h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn05m04m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn05m	0.66	2	0.65	0.994	2	1.000	0.61	0.970	2	1.000
	0.89	2	0.89	1.000	2	1.000	0.92	1.016	2	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
syn10h	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn10m02h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn10m02m	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn10m03h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.69	3	0.68	0.994	3	1.000	0.64	0.970	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn10m03m	0.78	3	0.78	1.000	3	1.000	0.76	0.989	3	1.000
	0.87	3	0.88	1.005	3	1.000	0.86	0.995	3	1.000
	0.60	2	0.59	0.994	2	1.000	0.61	1.006	2	1.000
syn10m04h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.63	2	0.59	0.975	2	1.000	0.63	1.000	2	1.000
	0.53	2	0.50	0.980	2	1.000	0.50	0.980	2	1.000
syn10m04m	1.10	4	1.09	0.995	4	1.000	1.10	1.000	4	1.000
	0.82	4	0.81	0.995	4	1.000	0.83	1.005	4	1.000
	0.56	3	0.54	0.987	3	1.000	0.59	1.019	3	1.000
syn10m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m02h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m02m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m03h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m03m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m04h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.56	2	0.56	1.000	2	1.000	0.57	1.006	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m04m	0.64	2	0.64	1.000	2	1.000	0.65	1.006	2	1.000
	1.01	2	0.98	0.985	2	1.000	1.00	0.995	2	1.000
	0.87	2	0.85	0.989	2	1.000	0.85	0.989	2	1.000
syn15m	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn20h	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn20m02h	0.53	2	0.50	0.980	2	1.000	0.51	0.987	2	1.000
	0.54	2	0.50	0.974	2	1.000	0.50	0.974	2	1.000
	0.84	2	0.86	1.011	2	1.000	0.84	1.000	2	1.000
syn20m02m	0.65	2	0.65	1.000	2	1.000	0.65	1.000	2	1.000
	0.57	2	0.58	1.006	2	1.000	0.58	1.006	2	1.000
	0.79	3	0.77	0.989	3	1.000	0.78	0.994	3	1.000
syn20m03h	0.55	1	0.54	0.994	1	1.000	0.53	0.987	1	1.000
	0.63	1	0.61	0.988	1	1.000	0.64	1.006	1	1.000
	0.53	1	0.51	0.987	1	1.000	0.53	1.000	1	1.000
syn20m03m	0.88	2	0.88	1.000	2	1.000	0.86	0.989	2	1.000
	1.16	2	1.17	1.005	2	1.000	1.18	1.009	2	1.000
	1.11	4	1.14	1.014	4	1.000	1.11	1.000	4	1.000
syn20m04h	1.24	2	1.22	0.991	2	1.000	1.22	0.991	2	1.000
	0.66	1	0.65	0.994	1	1.000	0.67	1.006	1	1.000
	0.93	1	0.94	1.005	1	1.000	0.89	0.979	1	1.000
syn20m04m	1.23	2	1.27	1.018	2	1.000	1.28	1.022	2	1.000
	2.00	2	2.00	1.000	2	1.000	2.00	1.000	2	1.000
	1.03	2	1.01	0.990	2	1.000	1.04	1.005	2	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
syn20m	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn30h	1.16	3	1.14	0.991	3	1.000	1.14	0.991	3	1.000
	0.86	19	0.81	0.973	19	1.000	0.84	0.989	19	1.000
	0.91	7	0.89	0.990	7	1.000	0.84	0.963	5	0.981
syn30m02h	1.38	47	1.35	0.987	47	1.000	1.41	1.013	47	1.000
	1.89	12	1.92	1.010	12	1.000	1.82	0.976	10	0.982
	1.91	27	1.89	0.993	27	1.000	1.90	0.997	27	1.000
syn30m02m	1.97	8	1.97	1.000	8	1.000	1.95	0.993	8	1.000
	2.32	9	2.33	1.003	9	1.000	2.32	1.000	9	1.000
	1.33	4	1.33	1.000	4	1.000	1.31	0.991	4	1.000
syn30m03h	2.47	30	2.52	1.014	30	1.000	2.56	1.026	30	1.000
	2.29	6	2.48	*1.058*	12	*1.057*	2.36	1.021	8	1.019
	2.30	63	2.32	1.006	63	1.000	2.31	1.003	63	1.000
syn30m03m	2.60	6	2.61	1.003	6	1.000	2.63	1.008	6	1.000
	2.16	8	2.12	0.987	8	1.000	2.14	0.994	8	1.000
	2.41	4	2.45	1.012	4	1.000	2.40	0.997	4	1.000
syn30m04h	3.61	153	3.54	0.985	153	1.000	3.58	0.993	153	1.000
	4.55	50	4.50	0.991	50	1.000	4.56	1.002	50	1.000
	3.10	24	3.12	1.005	24	1.000	3.05	0.988	24	1.000
syn30m04m	1.94	3	1.93	0.997	3	1.000	1.94	1.000	3	1.000
	2.35	6	2.26	0.973	6	1.000	2.30	0.985	6	1.000
	2.32	3	2.34	1.006	3	1.000	2.33	1.003	3	1.000
syn30m	0.82	4	0.83	1.005	4	1.000	0.81	0.995	4	1.000
	0.57	2	0.54	0.981	2	1.000	0.60	1.019	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn40h	1.33	12	1.32	0.996	12	1.000	1.29	0.983	11	0.991
	1.01	4	1.02	1.005	4	1.000	0.99	0.990	4	1.000
	0.96	46	0.96	1.000	46	1.000	0.95	0.995	46	1.000
syn40m02h	3.91	6	3.95	1.008	6	1.000	3.94	1.006	6	1.000
	1.62	124	1.61	0.996	124	1.000	1.62	1.000	124	1.000
	1.54	103	1.59	1.020	103	1.000	1.61	1.028	103	1.000
syn40m02m	2.28	4	2.29	1.003	4	1.000	2.28	1.000	4	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1.47	4	1.42	0.980	4	1.000	1.42	0.980	4	1.000
	2.18	17	2.30	1.038	17	1.000	2.21	1.009	17	1.000
syn40m03h	3.96	127	3.85	0.978	127	1.000	3.84	0.976	127	1.000
	4.20	216	4.14	0.988	216	1.000	4.25	1.010	216	1.000
	3.20	120	3.17	0.993	120	1.000	3.14	0.986	120	1.000
syn40m03m	2.64	6	2.65	1.003	4	0.981	2.70	1.016	4	0.981
	2.69	4	2.71	1.005	4	1.000	2.70	1.003	4	1.000
	6.02	10	5.97	0.993	10	1.000	6.01	0.999	10	1.000
syn40m04h	8.16	109	8.11	0.995	109	1.000	8.26	1.011	109	1.000
	6.28	114	6.16	0.984	114	1.000	6.32	1.005	114	1.000
	6.17	353	6.10	0.990	353	1.000	6.09	0.989	353	1.000
syn40m04m	5.84	38	5.80	0.994	38	1.000	5.90	1.009	38	1.000
	6.25	12	6.29	1.006	12	1.000	6.31	1.008	12	1.000
	6.93	14	6.84	0.989	14	1.000	6.96	1.004	14	1.000
syn40m	0.66	3	0.64	0.988	3	1.000	0.68	1.012	3	1.000
	0.79	3	0.73	0.966	3	1.000	0.78	0.994	3	1.000
	0.80	4	0.87	1.039	4	1.000	0.85	1.028	4	1.000
synheat	2.90%	1419752	2.57%	1.000	1309973	0.923	2.31%	1.000	1259809	0.887
	1.27%	14675604	1.27%	1.000	14716710	1.003	1.21%	1.000	9554803	0.651
	1.13%	7638984	1.35%	1.000	9487826	1.242	1.08%	1.000	6177958	0.809
synthes1	0.62	3	0.64	1.012	3	1.000	0.63	1.006	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
synthes2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
synthes3	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
tanksize	3.94	2301	3.96	1.004	2301	1.000	3.77	0.966	1871	**0.821**
	5.78	2789	5.75	0.996	2789	1.000	5.56	0.968	2291	**0.828**
	4.85	2271	4.84	0.998	2271	1.000	4.78	0.988	2031	**0.899**
telecomsp_metro	21.75%	2340	26.55%	1.000	2454	1.047	18.74%	1.000	2824	1.198
	18.85%	2255	16.17%	1.000	1991	0.888	24.22%	1.000	1386	0.631

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	20.98%	743	21.53%	1.000	704	0.954	16.23%	1.000	1964	2.448
telecomsp_njlata	6.61%	1568	11.30%	1.000	280	0.228	6.82%	1.000	1145	0.746
	7.60%	1881	6.96%	1.000	990	0.550	6.69%	1.000	2098	1.110
	6.40%	2725	6.31%	1.000	3831	1.392	12.61%	1.000	261	0.128
telecomsp_nor_sun	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
telecomsp_pacbell	1.96%	1543	1.59%	1.000	2197	1.398	1.19%	1.000	5630	3.488
	0.62%	7562	1.80%	1.000	1921	0.264	1.43%	1.000	2816	0.381
	1.50%	3879	0.61%	1.000	10541	2.674	0.79%	1.000	4124	1.062
tln12	1144.44%	82786	1109.88%	1.000	105233	1.271	1067.90%	1.000	98964	1.195
	1156.79%	76811	1112.35%	1.000	116280	1.513	1095.06%	1.000	107198	1.395
	1054.32%	89996	1088.89%	1.000	130754	1.452	1075.31%	1.000	117674	1.307
tln2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
tln4	1.49	1603	1.73	*1.096*	1696	*1.055*	1.52	1.012	1759	*1.092*
	1.97	2048	1.96	0.997	2056	1.004	1.96	0.997	2026	0.990
	1.91	2368	1.80	0.962	2285	0.966	1.61	**0.897**	1836	**0.784**
tln5	26.44	30447	27.28	1.031	30866	1.014	26.50	1.002	31134	1.022
	99.76	88674	61.00	**0.615**	62333	**0.703**	118.67	*1.188*	93992	*1.060*
	62.44	65953	54.49	**0.875**	58532	**0.888**	49.24	**0.792**	48502	**0.736**
tln6	77.88%	217429	86.74%	1.000	220656	1.015	90.34%	1.000	240056	1.104
	141.93%	244129	142.22%	1.000	246135	1.008	146.23%	1.000	248840	1.019
	145.11%	209270	146.77%	1.000	209892	1.003	139.78%	1.000	183269	0.876
tln7	295.31%	169336	346.30%	1.000	286526	1.692	306.28%	1.000	221660	1.309
	309.35%	170150	333.67%	1.000	306648	1.802	312.62%	1.000	261412	1.536
	288.35%	173123	322.57%	1.000	328334	1.896	308.91%	1.000	228484	1.320
tloss	0.50	23	0.50	1.000	27	1.033	0.50	1.000	30	*1.057*
	0.50	36	0.50	1.000	32	0.971	0.50	1.000	30	0.956
	0.56	72	0.50	0.962	46	**0.849**	0.72	*1.103*	178	*1.616*
tls12	∞	74102	∞	1.000	79233	1.069	∞	1.000	77458	1.045
	∞	119756	∞	1.000	114649	0.957	∞	1.000	115232	0.962
	∞	101189	∞	1.000	105608	1.044	∞	1.000	99497	0.983

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
tls2	0.50	17	0.50	1.000	17	1.000	0.50	1.000	15	0.983
	0.50	17	0.50	1.000	17	1.000	0.50	1.000	15	0.983
	0.50	17	0.50	1.000	17	1.000	0.50	1.000	15	0.983
tls4	14.51	6554	16.69	*1.141*	6540	0.998	15.72	*1.078*	6182	**0.944**
	14.42	7576	14.28	0.991	5573	**0.739**	15.19	1.050	5953	**0.789**
	20.52	12844	12.53	**0.629**	5923	**0.465**	13.14	**0.657**	6298	**0.494**
tls5	64.33%	907346	52.94%	1.000	1434627	1.581	52.10%	1.000	1465840	1.615
	71.45%	1049855	57.04%	1.000	1833834	1.747	63.49%	1.000	1314675	1.252
	86.59%	744553	59.56%	1.000	1224104	1.644	55.77%	1.000	1368044	1.837
tls6	387.92%	301114	439.88%	1.000	341366	1.134	513.68%	1.000	258694	0.859
	410.14%	272273	174.26%	1.000	304975	1.120	471.94%	1.000	277438	1.019
	313.51%	394296	384.61%	1.000	315345	0.800	180.15%	1.000	296213	0.751
tls7	4106.09%	428648	4015.04%	1.000	411334	0.960	4319.27%	1.000	385361	0.899
	4645.29%	280748	4238.00%	1.000	403237	1.436	3742.32%	1.000	555458	1.978
	3624.78%	537262	3865.20%	1.000	392820	0.731	3933.25%	1.000	391620	0.729
tltr	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
topopt-cantilever_60x40_50	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
topopt-mbb_60x40_50	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
topopt-zhou-rozvany_75	10.83%	1	10.83%	1.000	1	1.000	10.83%	1.000	1	1.000
	10.83%	55	10.83%	1.000	55	1.000	10.83%	1.000	55	1.000
toroidal2g20_5555	187.89%	565	187.85%	1.000	573	1.012	187.85%	1.000	572	1.011
	187.85%	569	187.85%	1.000	571	1.003	187.85%	1.000	573	1.006
	187.85%	571	187.85%	1.000	569	0.997	187.85%	1.000	571	1.000
toroidal3g7_6666	270.98%	1138	267.13%	1.000	1156	1.015	278.97%	1.000	1142	1.003
	270.98%	1138	267.13%	1.000	1156	1.015	256.65%	1.000	1151	1.011
	270.98%	1138	267.13%	1.000	1157	1.015	256.65%	1.000	1147	1.007
transswitch0009r	345.57%	206752	345.57%	1.000	198994	0.962	345.57%	1.000	206811	1.000
	345.57%	215607	345.57%	1.000	210863	0.978	345.57%	1.000	215553	1.000

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	345.57%	205488	345.57%	1.000	199890	0.973	345.57%	1.000	205570	1.000
transswitch0014r	∞	11102	∞	1.000	10745	0.968	∞	1.000	11088	0.999
	∞	33447	∞	1.000	32314	0.966	∞	1.000	33401	0.999
	∞	26728	∞	1.000	26062	0.975	∞	1.000	26881	1.006
transswitch0030r	∞	2250	∞	1.000	2248	0.999	∞	1.000	2250	1.000
	∞	1573	∞	1.000	1573	1.000	∞	1.000	1573	1.000
	∞	8283	∞	1.000	8242	0.995	∞	1.000	8288	1.001
transswitch0039r	∞	392	∞	1.000	392	1.000	∞	1.000	392	1.000
	∞	755	∞	1.000	763	1.009	∞	1.000	757	1.002
	∞	313	∞	1.000	317	1.010	∞	1.000	313	1.000
transswitch0057r	∞	210	∞	1.000	210	1.000	∞	1.000	210	1.000
	∞	535	∞	1.000	569	1.054	∞	1.000	535	1.000
	∞	2399	∞	1.000	2428	1.012	∞	1.000	2399	1.000
transswitch0118r	∞	10304	∞	1.000	10304	1.000	∞	1.000	10303	1.000
	∞	5166	∞	1.000	5166	1.000	∞	1.000	5166	1.000
	∞	1735	∞	1.000	1741	1.003	∞	1.000	1735	1.000
transswitch0300r	∞	80423	∞	1.000	80422	1.000	∞	1.000	80424	1.000
	∞	33136	∞	1.000	33136	1.000	∞	1.000	33136	1.000
	∞	721	∞	1.000	722	1.001	∞	1.000	721	1.000
transswitch2383wpr	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
transswitch2736spr	39.15%	1	39.15%	1.000	1	1.000	39.15%	1.000	1	1.000
	39.15%	1	39.15%	1.000	1	1.000	39.15%	1.000	1	1.000
	39.15%	1	39.15%	1.000	1	1.000	39.15%	1.000	1	1.000
tspn05	38.96	29221	41.56	*1.065*	32421	*1.109*	22.34	**0.584**	11261	**0.387**
	208.94	221561	190.42	**0.912**	201081	**0.908**	28.80	**0.142**	16301	**0.074**
	36.92	22361	73.97	*1.977*	59181	*2.639*	13.66	**0.387**	4951	**0.225**
tspn08	2.30%	634689	1.60%	1.000	603933	0.952	1.16%	1.000	583481	0.919
	3.70%	628767	2.56%	1.000	595515	0.947	3.52%	1.000	556743	0.885
	4.78%	891706	4.03%	1.000	955741	1.072	3.59%	1.000	774926	0.869
tspn10	17.88%	522485	7.70%	1.000	499440	0.956	7.39%	1.000	495630	0.949
	17.56%	551318	9.03%	1.000	567710	1.030	8.00%	1.000	534802	0.970
	18.01%	496173	6.70%	1.000	547590	1.104	7.53%	1.000	527199	1.063

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
tspn12	45.93%	335999	32.46%	1.000	309861	0.922	25.18%	1.000	286030	0.851
	49.35%	343488	32.20%	1.000	279424	0.814	33.02%	1.000	279310	0.813
	41.93%	304050	33.91%	1.000	252562	0.831	27.42%	1.000	230416	0.758
tspn15	22.34%	260148	21.27%	1.000	233372	0.897	21.02%	1.000	216326	0.832
	22.88%	286086	23.20%	1.000	287052	1.003	23.38%	1.000	275479	0.963
	22.72%	279089	22.38%	1.000	211425	0.758	21.85%	1.000	207696	0.744
unitcommit1	2.12	2	2.09	0.990	2	1.000	2.17	1.016	2	1.000
	2.32	2	2.33	1.003	2	1.000	2.31	0.997	2	1.000
	1.64	2	1.74	1.038	2	1.000	1.70	1.023	2	1.000
unitcommit2	19.52%	2434	19.51%	1.000	2455	1.008	19.51%	1.000	2442	1.003
	17.25%	2118	17.25%	1.000	2142	1.011	17.25%	1.000	2114	0.998
	16.49%	1929	16.42%	1.000	1958	1.014	16.49%	1.000	1934	1.002
unitcommit_200_100_1_mod_8	0.12%	334	0.11%	1.000	320	0.968	0.13%	1.000	227	0.753
	0.16%	28	0.10%	1.000	780	6.875	0.16%	1.000	28	1.000
	0.13%	67	0.13%	1.000	67	1.000	0.13%	1.000	67	1.000
unitcommit_200_100_2_mod_7	0.04%	5471	0.04%	1.000	3454	0.638	0.04%	1.000	4002	0.736
	0.04%	5016	0.04%	1.000	4667	0.932	0.04%	1.000	3084	0.622
unitcommit_200_100_2_mod_8	0.05%	256	0.06%	1.000	157	0.722	0.06%	1.000	183	0.795
	0.06%	704	0.06%	1.000	606	0.878	0.05%	1.000	651	0.934
	0.04%	632	0.05%	1.000	341	0.602	0.06%	1.000	192	0.399
unitcommit_50_20_2_mod_8	0.02%	48871	0.02%	1.000	48601	0.994	0.02%	1.000	45173	0.924
	0.02%	48336	0.02%	1.000	44301	0.917	0.02%	1.000	34207	0.708
	0.01%	42192	0.02%	1.000	38776	0.919	0.02%	1.000	42170	0.999
uselinear	∞	12054	∞	1.000	11947	0.991	∞	1.000	12300	1.020
	∞	7272	∞	1.000	7298	1.004	∞	1.000	3256	0.455
	∞	1303	∞	1.000	1303	1.000	∞	1.000	1303	1.000
util	0.57	37	0.58	1.006	33	0.971	0.59	1.013	33	0.971
	0.50	22	0.50	1.000	22	1.000	0.50	1.000	22	1.000
	0.50	17	0.50	1.000	17	1.000	0.50	1.000	17	1.000
waste	78.64%	2312198	78.62%	1.000	2287041	0.989	78.58%	1.000	2315354	1.001
	79.35%	2166976	79.38%	1.000	2148835	0.992	80.84%	1.000	2122147	0.979
wastepaper3	10.60	8503	10.75	1.013	8503	1.000	10.47	0.989	8503	1.000
	388.94	539080	337.27	**0.867**	457278	**0.848**	354.85	**0.913**	512493	0.951
	361.22	506259	381.76	*1.057*	521520	1.030	350.62	0.971	506753	1.001

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
wastepaper5	∞	9316050	∞	1.000	9044240	0.971	∞	1.000	8825077	0.947
	∞	9218549	∞	1.000	9016313	0.978	∞	1.000	8487485	0.921
wastepaper6	∞	6475561	∞	1.000	6606730	1.020	∞	1.000	6475547	1.000
	∞	7087161	∞	1.000	7208954	1.017	∞	1.000	6904735	0.974
	162.05%	2890296	149.25%	1.000	2433168	0.842	147.07%	1.000	1982887	0.686
water4	68.59%	3937338	67.13%	1.000	3734242	0.948	55.29%	1.000	3854790	0.979
	57.91%	4212386	52.28%	1.000	4172745	0.991	51.07%	1.000	4104686	0.974
	71.36%	3517147	69.65%	1.000	3873376	1.101	45.84%	1.000	4533838	1.289
watercontamination0202	202.80	39	201.97	0.996	39	1.000	202.00	0.996	39	1.000
	86.80	34	87.03	1.003	34	1.000	87.01	1.002	34	1.000
watercontamination0202r	203.22	7	203.87	1.003	7	1.000	203.91	1.003	7	1.000
	184.93	18	184.60	0.998	18	1.000	184.42	0.997	18	1.000
	1792.86	21	1820.03	1.015	21	1.000	1806.65	1.008	21	1.000
watercontamination0303	∞	91	2369.33	**0.329**	261	*1.890*	∞	1.000	123	1.168
	∞	131	∞	1.000	85	0.801	∞	1.000	85	0.801
	∞	188	∞	1.000	75	0.608	∞	1.000	75	0.608
watercontamination0303r	∞	16	∞	1.000	16	1.000	∞	1.000	16	1.000
	∞	16	∞	1.000	16	1.000	∞	1.000	16	1.000
	∞	16	∞	1.000	16	1.000	∞	1.000	16	1.000
waternd1	12.99	5040	13.18	1.014	5040	1.000	13.56	1.041	5040	1.000
	12.63	8441	12.50	0.990	8441	1.000	10.50	**0.844**	3988	**0.479**
waternd2	4.27%	2824623	2.10%	1.000	2739364	0.970	2.99%	1.000	2518380	0.892
	70.19%	2237805	5.90%	1.000	2367044	1.058	4.26%	1.000	2290732	1.024
	3.22%	2549690	1.81%	1.000	1804746	0.708	1.98%	1.000	1831971	0.719
	∞	378241	3.16%	1.000	1425598	3.768	∞	1.000	1794357	4.743
waternd_fosspoly0	∞	1332033	∞	1.000	1328708	0.998	∞	1.000	1529540	1.148
	∞	838621	∞	1.000	1066200	1.271	∞	1.000	1261807	1.505
	∞	1846435	∞	1.000	1666569	0.903	∞	1.000	1748965	0.947
waternd_hanoi	297.36	71193	300.25	1.010	78098	*1.097*	290.12	0.976	71054	0.998
	405.97	102387	199.71	**0.493**	50508	**0.494**	439.55	*1.083*	104059	1.016
waternd_modena	∞	283252	∞	1.000	352851	1.246	∞	1.000	221776	0.783
	∞	333389	∞	1.000	417924	1.253	∞	1.000	188349	0.565
	∞	310944	∞	1.000	421657	1.356	∞	1.000	168616	0.542

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
waternd_pescara	∞	394314	∞	1.000	428722	1.087	∞	1.000	397009	1.007
	∞	292334	∞	1.000	314723	1.077	∞	1.000	353493	1.209
	∞	426342	∞	1.000	383559	0.900	∞	1.000	430058	1.009
waternd_shamir	8.04	4317	6.37	**0.815**	2457	**0.579**	7.91	0.986	3430	**0.799**
	10.66	5541	10.80	1.012	5886	*1.061*	9.91	**0.936**	5104	**0.923**
	9.55	5221	8.30	**0.882**	3991	**0.769**	6.99	**0.757**	3029	**0.588**
waterno1_01	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	3.40	323	2.92	**0.891**	247	**0.820**	3.73	*1.075*	336	1.031
waterno1_03	9.40	1004	15.42	*1.579*	1692	*1.623*	7.53	**0.820**	942	**0.944**
	14.60	2121	18.50	*1.250*	3751	*1.734*	20.70	*1.391*	3041	*1.414*
	14.78	2102	13.58	**0.924**	1932	**0.923**	9.33	**0.655**	912	**0.460**
	36.87	5031	41.86	*1.132*	4701	**0.936**	35.82	0.972	3751	**0.751**
waterno1_18	17.38%	106340	16.31%	1.000	114569	1.077	17.12%	1.000	101536	0.955
	13.42%	189041	13.61%	1.000	143986	0.762	18.10%	1.000	115269	0.610
	13.85%	165518	14.79%	1.000	128487	0.776	32.36%	1.000	23295	0.141
	19.18%	117698	19.65%	1.000	41461	0.353	19.04%	1.000	88145	0.749
waterno2_01	0.76	10	0.76	1.000	10	1.000	0.75	0.994	10	1.000
	0.56	14	0.57	1.006	14	1.000	0.57	1.006	14	1.000
	0.59	16	0.60	1.006	16	1.000	0.61	1.013	16	1.000
waterno2_02	2.82	332	2.85	1.008	332	1.000	2.76	0.984	332	1.000
	2.39	292	2.32	0.979	292	1.000	2.38	0.997	292	1.000
	2.45	231	2.48	1.009	231	1.000	2.45	1.000	231	1.000
waterno2_03	350.14	119416	433.43	*1.237*	178603	*1.495*	415.79	*1.187*	166631	*1.395*
	297.79	95243	318.30	*1.069*	103613	*1.088*	317.64	*1.066*	103613	*1.088*
	277.48	70395	275.26	0.992	70395	1.000	274.08	0.988	68965	0.980
waterno2_04	38.47%	516725	7.02%	1.000	1303292	2.522	10.64%	1.000	636099	1.231
	53.70%	1030853	14.65%	1.000	863998	0.838	13.60%	1.000	972192	0.943
waterno2_09	851.42%	228087	868.70%	1.000	230269	1.010	851.17%	1.000	223483	0.980
	1022.77%	179647	836.78%	1.000	187216	1.042	796.89%	1.000	189121	1.053
waterno2_12	1162.18%	194790	961.86%	1.000	193058	0.991	883.13%	1.000	205113	1.053
	887.00%	178498	1264.23%	1.000	158008	0.885	1049.77%	1.000	175884	0.985
	982.93%	167793	1025.64%	1.000	168672	1.005	1116.77%	1.000	167326	0.997
waterno2_24	≥ 10000%	25733	8972.58%	1.000	33360	1.295	≥ 10000%	1.000	65654	2.545

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Table E.1: Detailed computational results on MinlpLib.

	nolpinf		confgraph				combined			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	3868.89%	48368	3762.41%	1.000	43693	0.904	4018.60%	1.000	44959	0.930
waters	150.31%	5126692	152.75%	1.000	4906585	0.957	145.27%	1.000	4805319	0.937
	210.76%	5082985	184.81%	1.000	5295050	1.042	200.63%	1.000	4378686	0.861
	267.13%	4740514	268.80%	1.000	4891697	1.032	255.07%	1.000	5317788	1.122
watersbp	80.90%	5393949	88.03%	1.000	8268102	1.533	77.83%	1.000	6445388	1.195
	96.79%	5750280	88.88%	1.000	5951537	1.035	78.09%	1.000	6295945	1.095
	114.93%	6374064	92.32%	1.000	6387244	1.002	116.15%	1.000	3080734	0.483
watersym1	87.75%	1441507	70.43%	1.000	1220936	0.847	67.17%	1.000	930345	0.645
	13.60	11211	13.76	1.011	11211	1.000	15.36	*1.121*	12351	*1.101*
	49.10	65951	49.44	1.007	65951	1.000	484.12	*9.683*	415461	*6.292*
	0.69%	10124086	0.69%	1.000	10010702	0.989	1.29%	1.000	8159452	0.806
watertreatnd_flow	102.05	45948	102.57	1.005	45948	1.000	102.39	1.003	45948	1.000
	34.40	12441	34.28	0.997	12441	1.000	34.53	1.004	12441	1.000
	95.59	54988	96.12	1.005	54988	1.000	274.37	*2.851*	170696	*3.100*
waterx	11.53%	748542	10.93%	1.000	751213	1.004	12.62%	1.000	744478	0.995
	12.27%	776202	12.20%	1.000	766270	0.987	11.52%	1.000	698280	0.900
waterz	179.33%	11503462	175.44%	1.000	10035505	0.872	524.99%	1.000	311582	0.027
	1500.39%	21924	927.06%	1.000	106584	4.844	1107.79%	1.000	89679	4.076
	1121.83%	52363	1084.04%	1.000	55809	1.066	224.49%	1.000	8250171	157.259

Table E.2: Detailed computational results on nonconvex instances of MinlpLib. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
4stufen	∞	26	∞	1.000	26	1.000	∞	1.000	26	1.000
	∞	27	∞	1.000	27	1.000	∞	1.000	27	1.000
	33.02%	1351887	30.43%	1.000	1466966	1.085	30.59%	1.000	1610251	1.191
alan	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
autocorr_bern20-03	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
autocorr_bern20-05	52.77	36163	50.17	0.952	33679	**0.932**	49.87	**0.946**	33679	**0.932**
	53.02	36163	50.31	**0.950**	33679	**0.932**	50.15	**0.947**	33679	**0.932**
	52.73	36163	49.84	**0.946**	33679	**0.932**	49.93	**0.948**	33679	**0.932**
autocorr_bern20-10	491.69	169917	488.03	0.993	170120	1.001	494.96	1.007	168234	0.990
	495.49	173068	494.40	0.998	171171	0.989	495.20	0.999	171317	0.990
	501.46	184617	498.15	0.993	172255	**0.933**	498.36	0.994	172255	**0.933**
autocorr_bern20-15	949.24	168894	996.70	1.050	169986	1.006	998.59	*1.052*	169438	1.003
	945.28	168894	991.63	1.049	169986	1.006	993.87	*1.051*	169438	1.003
	943.81	168894	988.21	1.047	169986	1.006	997.59	*1.057*	169438	1.003
autocorr_bern25-03	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
autocorr_bern25-06	1151.54	1060923	1070.98	**0.930**	956501	**0.902**	1127.22	0.979	959820	**0.905**
	1053.56	932298	1141.22	*1.083*	1060245	*1.137*	1010.76	0.959	820937	**0.881**
	1219.57	1077557	1172.95	0.962	1039728	0.965	1004.82	**0.824**	859688	**0.798**
autocorr_bern25-13	97.55%	1064153	97.55%	1.000	1064092	1.000	97.52%	1.000	1064711	1.001
	97.96%	1057004	97.60%	1.000	1063055	1.006	97.52%	1.000	1064558	1.007
	98.03%	1056399	97.78%	1.000	1060282	1.004	97.30%	1.000	1069275	1.012
autocorr_bern25-19	134.87%	562861	152.64%	1.000	450391	0.800	155.07%	1.000	434572	0.772
	135.12%	560870	151.93%	1.000	454617	0.811	155.86%	1.000	430194	0.767
	134.79%	563583	152.54%	1.000	450832	0.800	156.18%	1.000	428639	0.761
autocorr_bern25-25	342.02%	328682	353.77%	1.000	289911	0.882	354.43%	1.000	287812	0.876
	373.18%	286811	389.32%	1.000	247944	0.865	407.44%	1.000	214218	0.747
	350.53%	322253	409.03%	1.000	204955	0.636	408.18%	1.000	207123	0.643

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
autocorr_bern30-04	463.70	668272	567.49	*1.223*	824450	*1.234*	568.26	*1.225*	824450	*1.234*
	477.45	702459	526.68	*1.103*	753958	*1.073*	528.00	*1.106*	753958	*1.073*
	547.95	805399	600.81	*1.096*	891728	*1.107*	600.03	*1.095*	891728	*1.107*
autocorr_bern30-08	202.04%	1448144	202.73%	1.000	1472244	1.017	201.82%	1.000	1470934	1.016
	207.67%	1516624	198.10%	1.000	1426595	0.941	206.93%	1.000	1426295	0.940
	205.87%	1513474	213.66%	1.000	1335590	0.882	205.50%	1.000	1460394	0.965
autocorr_bern30-15	229.66%	509542	227.94%	1.000	555814	1.091	228.35%	1.000	552213	1.084
	229.26%	513359	228.32%	1.000	552437	1.076	227.93%	1.000	555854	1.083
	229.80%	508534	228.01%	1.000	555074	1.091	228.15%	1.000	554067	1.090
autocorr_bern30-23	508.08%	88265	565.12%	1.000	63291	0.717	565.56%	1.000	63082	0.715
	506.76%	88982	565.45%	1.000	63197	0.711	565.39%	1.000	63265	0.711
	507.99%	88352	565.57%	1.000	63054	0.714	565.12%	1.000	63291	0.717
autocorr_bern30-30	1483.85%	66	1483.85%	1.000	66	1.000	1483.85%	1.000	66	1.000
	1483.85%	66	1483.85%	1.000	66	1.000	1483.85%	1.000	66	1.000
	1483.85%	66	1483.85%	1.000	66	1.000	1483.85%	1.000	66	1.000
autocorr_bern35-04	2692.43	3871001	3979.89	*1.478*	5243100	*1.354*	3991.62	*1.482*	5243100	*1.354*
	5636.04	7464527	4934.99	**0.876**	5548734	**0.743**	4943.46	**0.877**	5549162	**0.743**
	2700.58	3575852	2619.70	0.970	3599710	1.007	2606.07	0.965	3599710	1.007
autocorr_bern35-09	487.91%	590796	483.63%	1.000	624181	1.056	474.07%	1.000	642056	1.087
	426.06%	635177	427.86%	1.000	619435	0.975	427.36%	1.000	622437	0.980
	463.86%	665317	422.10%	1.000	729013	1.096	421.72%	1.000	731736	1.100
autocorr_bern35-18	464.77%	18161	464.43%	1.000	17601	0.969	463.20%	1.000	17840	0.982
	463.75%	18403	463.74%	1.000	17783	0.966	464.23%	1.000	17662	0.960
	464.65%	18190	464.25%	1.000	17644	0.970	464.68%	1.000	17555	0.965
autocorr_bern35-26	796.04%	26912	823.89%	1.000	18462	0.687	819.47%	1.000	18601	0.692
	796.11%	26779	823.89%	1.000	18451	0.690	823.89%	1.000	18460	0.691
	796.06%	26791	824.13%	1.000	18377	0.687	819.47%	1.000	18606	0.696
autocorr_bern35-35	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
autocorr_bern35-35fix	1051.92%	13522	1059.01%	1.000	13402	0.991	1059.01%	1.000	13402	0.991
	1052.42%	13265	1057.80%	1.000	13481	1.016	1059.71%	1.000	13331	1.005
	1052.19%	13431	1057.91%	1.000	13462	1.002	1058.20%	1.000	13451	1.001
autocorr_bern40-05	228.25%	1217445	227.12%	1.000	1153835	0.948	227.50%	1.000	1156465	0.950

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	226.52%	1207655	234.75%	1.000	1186565	0.983	225.45%	1.000	1194265	0.989
	226.79%	1184934	226.36%	1.000	1204905	1.017	226.76%	1.000	1208793	1.020
autocorr_bern40-10	689.08%	212755	700.37%	1.000	193733	0.911	700.28%	1.000	193871	0.911
	689.31%	212266	700.14%	1.000	194345	0.916	700.28%	1.000	193951	0.914
	689.19%	212642	700.14%	1.000	194345	0.914	700.44%	1.000	193654	0.911
autocorr_bern40-20	771.48%	32585	774.73%	1.000	31144	0.956	774.86%	1.000	31105	0.955
	771.18%	32731	773.96%	1.000	31353	0.958	773.96%	1.000	31352	0.958
	771.31%	32693	774.37%	1.000	31314	0.958	774.37%	1.000	31351	0.959
autocorr_bern40-30	1075.80%	10114	1439.39%	1.000	1671	0.173	1439.39%	1.000	1671	0.173
	1075.75%	10142	1439.39%	1.000	1671	0.173	1439.39%	1.000	1671	0.173
	1074.33%	10181	1439.39%	1.000	1671	0.172	1439.39%	1.000	1672	0.172
autocorr_bern45-05	284.44%	962976	266.25%	1.000	1045496	1.086	272.61%	1.000	983155	1.021
	255.13%	821226	248.58%	1.000	818156	0.996	246.29%	1.000	839726	1.023
	229.91%	855693	241.67%	1.000	837766	0.979	241.77%	1.000	809535	0.946
autocorr_bern45-11	974.61%	53532	973.52%	1.000	53331	0.996	974.61%	1.000	52993	0.990
	974.80%	53530	974.89%	1.000	52731	0.985	974.13%	1.000	53117	0.992
	979.05%	50751	975.97%	1.000	52292	1.030	975.42%	1.000	52467	1.034
autocorr_bern45-23	1461.68%	230	1461.68%	1.000	230	1.000	1461.68%	1.000	230	1.000
	1461.68%	230	1461.68%	1.000	230	1.000	1461.68%	1.000	230	1.000
	1461.68%	230	1461.68%	1.000	230	1.000	1461.68%	1.000	230	1.000
autocorr_bern50-06	555.48%	618825	559.16%	1.000	615996	0.995	558.46%	1.000	619566	1.001
	563.34%	670193	572.10%	1.000	619656	0.925	572.15%	1.000	618906	0.923
	564.49%	593334	561.97%	1.000	623547	1.051	556.79%	1.000	628106	1.059
autocorr_bern50-13	1504.10%	27	1504.10%	1.000	27	1.000	1504.10%	1.000	27	1.000
	1504.10%	27	1504.10%	1.000	27	1.000	1504.10%	1.000	27	1.000
	1504.10%	27	1504.10%	1.000	27	1.000	1504.10%	1.000	27	1.000
autocorr_bern50-25	1195.49%	1366	1190.01%	1.000	1667	1.205	1190.01%	1.000	1676	1.211
	1200.05%	1356	1188.33%	1.000	1684	1.225	1190.01%	1.000	1680	1.223
	1195.49%	1364	1190.01%	1.000	1680	1.216	1190.01%	1.000	1681	1.217
autocorr_bern50-50	1589.91%	627	1589.91%	1.000	623	0.994	1589.91%	1.000	625	0.997
	1589.91%	625	1589.91%	1.000	627	1.003	1589.91%	1.000	625	1.000
	1589.91%	627	1589.91%	1.000	624	0.996	1589.91%	1.000	624	0.996
autocorr_bern55-06	614.67%	422642	617.36%	1.000	411382	0.973	621.95%	1.000	419612	0.993
	637.26%	487076	638.97%	1.000	480353	0.986	638.93%	1.000	480776	0.987

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	665.01%	472967	665.56%	1.000	419246	0.886	665.49%	1.000	419666	0.887
autocorr_bern55-14	1615.30%	19	1615.30%	1.000	19	1.000	1615.30%	1.000	19	1.000
	1615.30%	19	1615.30%	1.000	19	1.000	1615.30%	1.000	19	1.000
	1615.30%	19	1615.30%	1.000	19	1.000	1615.30%	1.000	19	1.000
autocorr_bern55-28	1961.67%	25	1961.67%	1.000	25	1.000	1961.67%	1.000	25	1.000
	1961.67%	25	1961.67%	1.000	25	1.000	1961.67%	1.000	25	1.000
	1961.67%	25	1961.67%	1.000	25	1.000	1961.67%	1.000	25	1.000
autocorr_bern55-41	1719.76%	485	1719.76%	1.000	474	0.981	1719.76%	1.000	467	0.969
	1719.76%	484	1719.76%	1.000	455	0.950	1719.76%	1.000	474	0.983
autocorr_bern60-08	1003.02%	95554	1000.88%	1.000	98005	1.026	1000.76%	1.000	98234	1.028
	999.92%	99036	999.92%	1.000	99035	1.000	1000.22%	1.000	98814	0.998
	1000.65%	98364	1000.22%	1.000	98802	1.004	1000.23%	1.000	98683	1.003
autocorr_bern60-15	1608.28%	25	1608.28%	1.000	25	1.000	1608.28%	1.000	25	1.000
	1608.28%	25	1608.28%	1.000	25	1.000	1608.28%	1.000	25	1.000
	1608.28%	25	1608.28%	1.000	25	1.000	1608.28%	1.000	25	1.000
autocorr_bern60-45	1821.82%	20	1821.82%	1.000	20	1.000	1821.82%	1.000	20	1.000
	1821.82%	20	1821.82%	1.000	20	1.000	1821.82%	1.000	20	1.000
	1821.82%	20	1821.82%	1.000	20	1.000	1821.82%	1.000	20	1.000
autocorr_bern60-60	≥ 10000%	8	≥ 10000%	1.000	9	1.009	≥ 10000%	1.000	8	1.000
	≥ 10000%	8	≥ 10000%	1.000	8	1.000	≥ 10000%	1.000	8	1.000
	≥ 10000%	8	≥ 10000%	1.000	9	1.009	≥ 10000%	1.000	8	1.000
ball_mk2_10	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ball_mk2_30	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ball_mk3_10	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
ball_mk3_20	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ball_mk3_30	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ball_mk4_05	0.96	1913	0.86	**0.949**	1007	**0.550**	0.84	**0.939**	1007	**0.550**
	0.96	1913	0.85	**0.944**	1007	**0.550**	0.87	0.954	1007	**0.550**
	0.92	1913	0.85	0.964	1007	**0.550**	0.87	0.974	1007	**0.550**
ball_mk4_10	1170.38	2099707	576.78	**0.493**	1177625	**0.561**	575.16	**0.492**	1177625	**0.561**
	1171.00	2099707	577.94	**0.494**	1177625	**0.561**	576.10	**0.492**	1177625	**0.561**
	1169.01	2099707	574.79	**0.492**	1177625	**0.561**	578.51	**0.495**	1177625	**0.561**
ball_mk4_15	∞	3175514	∞	1.000	3459469	1.089	∞	1.000	3434403	1.082
	∞	3107824	∞	1.000	3466224	1.115	∞	1.000	3366925	1.083
	∞	3145049	∞	1.000	3440102	1.094	∞	1.000	3408485	1.084
batch0812	0.78	3	0.78	1.000	3	1.000	0.79	1.006	3	1.000
	1.29	3	1.27	0.991	3	1.000	1.29	1.000	3	1.000
	0.74	3	0.75	1.006	3	1.000	0.77	1.017	3	1.000
batch0812_nc	3.64	262	3.68	1.009	262	1.000	3.61	0.994	262	1.000
	2.89	4	2.92	1.008	4	1.000	2.96	1.018	4	1.000
batch	1.06	2	1.11	1.024	2	1.000	1.08	1.010	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.76	2	0.76	1.000	2	1.000	0.76	1.000	2	1.000
batch_nc	2.41	181	2.38	0.991	181	1.000	2.43	1.006	181	1.000
	1.98	162	2.01	1.010	162	1.000	1.97	0.997	162	1.000
	3.26	281	3.24	0.995	281	1.000	3.31	1.012	281	1.000
batchdes	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
batchs101006m	8.35	521	5.05	**0.647**	101	**0.324**	5.06	**0.648**	101	**0.324**
	7.50	234	6.33	**0.862**	199	**0.895**	6.42	**0.873**	199	**0.895**
	9.93	522	6.97	**0.729**	190	**0.466**	6.97	**0.729**	190	**0.466**
batchs121208m	21.61	533	15.61	**0.735**	78	**0.281**	15.56	**0.732**	78	**0.281**
	14.60	122	18.80	*1.269*	443	*2.446*	18.84	*1.272*	443	*2.446*
	17.75	450	13.74	**0.786**	293	**0.715**	13.64	**0.781**	293	**0.715**
batchs151208m	17.00	1263	17.44	1.024	1245	0.987	17.80	1.044	1245	0.987
	13.24	552	10.10	**0.779**	281	**0.584**	10.17	**0.784**	281	**0.584**
	23.84	1581	17.98	**0.764**	904	**0.597**	18.10	**0.769**	904	**0.597**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
batchs201210m	20.64	879	19.21	**0.934**	779	**0.898**	19.39	**0.942**	779	**0.898**
	37.00	3794	25.40	**0.695**	2299	**0.616**	25.47	**0.697**	2299	**0.616**
	10.11	186	9.38	**0.934**	193	1.024	9.43	**0.939**	193	1.024
bchoco05	5.05%	2695165	5.15%	1.000	2836035	1.052	5.15%	1.000	3207348	1.190
	5.14%	1654056	5.15%	1.000	2985583	1.805	5.15%	1.000	1243250	0.752
	5.15%	4041334	5.15%	1.000	5862141	1.451	5.15%	1.000	1183667	0.293
bchoco06	4.46%	3408722	4.46%	1.000	3338983	0.980	4.46%	1.000	3188481	0.935
	3.86%	3015452	3.86%	1.000	3293641	1.092	3.86%	1.000	4392021	1.456
	∞	2523974	∞	1.000	301178	0.119	4.46%	1.000	2654794	1.052
bchoco07	∞	43	∞	1.000	43	1.000	∞	1.000	43	1.000
	4.45%	2691588	4.45%	1.000	2693474	1.001	4.45%	1.000	2685910	0.998
	∞	146	∞	1.000	146	1.000	∞	1.000	146	1.000
bchoco08	1.02	3	1.03	1.005	3	1.000	1.03	1.005	3	1.000
	∞	32891	∞	1.000	32891	1.000	∞	1.000	87784	2.664
	∞	13895	∞	1.000	13895	1.000	∞	1.000	14412	1.037
beuster	1340.95%	41818	1340.95%	1.000	41818	1.000	∞	1.000	2729	0.067
	∞	6306	∞	1.000	6306	1.000	554.22%	1.000	5301070	827.532
	∞	7533	∞	1.000	7533	1.000	∞	1.000	11207	1.481
blend029	4.55	3317	4.57	1.004	3317	1.000	4.66	1.020	3141	**0.948**
	9.47	6202	8.58	**0.915**	6554	*1.056*	8.22	**0.881**	7322	*1.178*
	4.81	2509	4.92	1.019	2451	0.978	4.62	0.967	2483	0.990
blend146	4657.71	4865371	5148.42	*1.105*	5350331	*1.100*	3017.32	**0.648**	2632484	**0.541**
	169.38	112266	122.12	**0.723**	67256	**0.599**	85.93	**0.510**	51498	**0.459**
	48.55	27408	47.64	0.982	29822	*1.088*	48.56	1.000	28926	*1.055*
	141.74	74833	39.18	**0.281**	12025	**0.162**	82.76	**0.587**	32037	**0.429**
blend718	39.11%	5415586	35.43%	1.000	5474564	1.011	1688.62	**0.235**	1487637	**0.275**
	4214.01	3800829	3557.27	**0.844**	3178101	**0.836**	21.72%	1.708	4598903	1.210
	3303.28	2831792	3461.61	1.048	3239623	*1.144*	32.48%	2.179	4711570	1.664
blend721	57.03	25713	51.39	**0.903**	21735	**0.846**	34.78	**0.617**	13567	**0.529**
	21.20	8080	40.72	*1.879*	18388	*2.260*	58.14	*2.664*	29013	*3.559*
	44.31	23380	40.83	**0.923**	19425	**0.832**	41.73	**0.943**	18472	**0.791**
cardqp_inlp	70.57%	190313	69.86%	1.000	190535	1.001	75.93%	1.000	169712	0.892
	70.37%	192107	69.88%	1.000	190289	0.991	67.88%	1.000	201180	1.047
	70.26%	192852	69.88%	1.000	190289	0.987	71.62%	1.000	185836	0.964

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
cardqp_iqp	70.40%	191847	70.03%	1.000	188835	0.984	75.93%	1.000	169803	0.885
	70.37%	192104	69.88%	1.000	190289	0.991	68.06%	1.000	199969	1.041
	70.35%	192334	69.98%	1.000	189296	0.984	71.69%	1.000	184971	0.962
carton7	322.77	349796	353.03	*1.093*	383766	*1.097*	431.20	*1.335*	476658	*1.363*
	395.54	404154	736.67	*1.860*	632151	*1.564*	567.63	*1.434*	511430	*1.265*
	356.86	400729	310.52	**0.871**	344132	**0.859**	310.63	**0.871**	344132	**0.859**
carton9	46.96%	3913948	53.49%	1.000	1944616	0.497	56.92%	1.000	2084608	0.533
	120.39%	3112599	100.64%	1.000	3980588	1.279	106.22%	1.000	4009268	1.288
	172.00%	2449627	142.14%	1.000	2527996	1.032	128.97%	1.000	3458476	1.412
casctanks	302.20	30141	301.65	0.998	30141	1.000	294.07	0.973	29321	0.973
	0.34%	321823	0.34%	1.000	321596	0.999	4181.54	**0.581**	179701	**0.559**
case_1scv2	∞	76149	∞	1.000	52493	0.690	∞	1.000	52632	0.692
	∞	29097	∞	1.000	151047	5.177	∞	1.000	151010	5.176
	∞	30897	∞	1.000	47031	1.521	∞	1.000	45991	1.487
celar6-sub0	∞	480946	∞	1.000	496636	1.033	∞	1.000	483662	1.006
	∞	522985	∞	1.000	491885	0.941	∞	1.000	490455	0.938
	∞	517104	∞	1.000	476693	0.922	∞	1.000	484660	0.937
chp_partload	∞	71	∞	1.000	71	1.000	∞	1.000	71	1.000
	∞	97	∞	1.000	110	1.066	∞	1.000	110	1.066
	∞	100	∞	1.000	100	1.000	∞	1.000	100	1.000
chp_shorttermplan1a	15.12	26	15.07	0.997	24	0.984	15.15	1.002	24	0.984
	11.40	12	11.44	1.003	13	1.009	11.57	1.014	13	1.009
	12.09	50	12.94	*1.065*	46	0.973	12.82	*1.056*	46	0.973
chp_shorttermplan1b	0.99%	502942	1.74%	1.000	294927	0.586	1.74%	1.000	293500	0.584
	0.68%	386715	0.87%	1.000	381611	0.987	0.87%	1.000	382111	0.988
	2.24%	324675	1.46%	1.000	260409	0.802	1.46%	1.000	260491	0.802
chp_shorttermplan2a	57.41	291	12.70	**0.235**	21	**0.309**	12.66	**0.234**	21	**0.309**
	142.89	2319	155.24	*1.086*	2413	1.039	150.55	*1.053*	1430	**0.632**
	114.76	190	96.78	**0.845**	1333	*4.941*	89.48	**0.782**	1331	*4.934*
chp_shorttermplan2b	1.35%	133441	1.05%	1.000	176379	1.322	1.54%	1.000	93287	0.699
	0.80%	156100	0.75%	1.000	159768	1.023	1.67%	1.000	81781	0.524
	0.77%	200907	1.15%	1.000	177585	0.884	1.10%	1.000	188692	0.939
chp_shorttermplan2c	∞	75073	∞	1.000	78212	1.042	∞	1.000	87125	1.160
	∞	76690	∞	1.000	78038	1.018	∞	1.000	84245	1.098

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	74930	∞	1.000	85829	1.145	∞	1.000	90316	1.205
chp_shorttermplan2d	3.33%	95265	3.17%	1.000	92093	0.967	6.24%	1.000	88726	0.931
	∞	108117	∞	1.000	113896	1.053	6.51%	1.000	94906	0.878
	4.63%	144371	3.93%	1.000	125254	0.868	4.00%	1.000	138907	0.962
clay0203h	5.37	441	5.42	1.008	441	1.000	5.43	1.009	441	1.000
	0.99	26	0.99	1.000	26	1.000	1.01	1.010	26	1.000
	0.94	59	0.93	0.995	55	0.975	0.92	0.990	55	0.975
	0.77	55	0.76	0.994	55	1.000	0.76	0.994	55	1.000
clay0204h	14.11	1012	13.83	0.981	976	0.968	14.01	0.993	940	**0.935**
	16.45	1235	15.47	**0.944**	973	**0.804**	15.90	0.968	1150	**0.936**
	16.16	1155	16.64	1.028	1216	1.049	15.62	0.969	1117	0.970
clay0204m	1.70	550	1.80	1.037	515	**0.946**	1.79	1.033	515	**0.946**
	1.94	467	1.90	0.986	510	*1.076*	2.00	1.020	510	*1.076*
	1.57	509	1.31	**0.899**	480	0.952	1.28	**0.887**	480	0.952
clay0205h	135.58	10890	120.56	**0.890**	17590	*1.610*	110.55	**0.817**	13820	*1.267*
	86.91	8022	77.05	**0.888**	7722	0.963	93.18	*1.071*	8546	*1.065*
	100.66	10307	131.44	*1.303*	15162	*1.467*	121.26	*1.203*	18750	*1.811*
clay0205m	4.58	2749	5.13	*1.099*	3042	*1.103*	5.17	*1.106*	3042	*1.103*
	6.54	2864	6.88	1.045	3531	*1.225*	6.78	1.032	3531	*1.225*
	5.59	3163	6.12	*1.080*	3882	*1.220*	6.17	*1.088*	3882	*1.220*
clay0303h	4.15	214	4.16	1.002	214	1.000	4.74	*1.115*	339	*1.398*
	6.63	451	6.60	0.996	451	1.000	7.63	*1.131*	1291	*2.525*
	7.44	435	7.45	1.001	435	1.000	6.28	**0.863**	443	1.015
clay0303m	1.62	15	1.62	1.000	15	1.000	1.61	0.996	15	1.000
	1.67	61	1.66	0.996	61	1.000	1.66	0.996	61	1.000
	2.32	163	2.36	1.012	163	1.000	2.36	1.012	163	1.000
clay0304m	2.42	318	2.52	1.029	257	**0.854**	2.51	1.026	257	**0.854**
	1.91	339	1.70	**0.928**	267	**0.836**	1.73	**0.938**	267	**0.836**
	2.12	170	2.05	0.978	169	0.996	2.06	0.981	169	0.996
clay0305h	163.22	14047	161.46	0.989	13482	0.960	113.25	**0.696**	10385	**0.741**
	118.96	12057	103.11	**0.868**	10537	**0.875**	115.54	0.971	11815	0.980
	119.89	11979	115.44	0.963	11750	0.981	96.74	**0.809**	11061	**0.924**
clay0305m	6.12	3711	6.59	*1.066*	4748	*1.272*	6.61	*1.069*	4748	*1.272*
	8.39	3708	8.21	0.981	3676	0.992	8.21	0.981	3676	0.992

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	8.06	2748	7.74	0.965	2857	1.038	7.95	0.988	2857	1.038
color_lab2_4x0	7641.40%	309082	≥ 10000%	1.000	215224	0.696	≥ 10000%	1.000	215289	0.697
	2045.62%	197211	2413.76%	1.000	225845	1.145	2395.58%	1.000	227295	1.152
	1797.58%	214899	1681.59%	1.000	322658	1.501	1681.99%	1.000	322444	1.500
color_lab3_3x0	92.35%	2010699	96.99%	1.000	1720449	0.856	96.99%	1.000	1720815	0.856
	91.15%	1884899	85.49%	1.000	1098706	0.583	85.49%	1.000	1098420	0.583
	90.42%	1826299	92.01%	1.000	1645599	0.901	92.00%	1.000	1647587	0.902
color_lab3_4x0	234.55%	323970	304.36%	1.000	1175073	3.626	304.27%	1.000	1179573	3.640
	229.66%	394330	238.11%	1.000	329820	0.836	238.18%	1.000	328775	0.834
	235.69%	361819	226.11%	1.000	371790	1.028	226.26%	1.000	369570	1.021
color_lab6b_4x20	∞	86085	∞	1.000	74448	0.865	∞	1.000	74448	0.865
	∞	37281	∞	1.000	44385	1.190	∞	1.000	44385	1.190
	∞	32493	∞	1.000	41997	1.292	∞	1.000	42070	1.294
contvar	105.93%	96724	106.62%	1.000	86566	0.895	108.00%	1.000	90230	0.933
	∞	69	∞	1.000	69	1.000	∞	1.000	69	1.000
	∞	22	∞	1.000	22	1.000	∞	1.000	22	1.000
crossdock_15x7	∞	43032	∞	1.000	46061	1.070	∞	1.000	46258	1.075
	∞	38593	∞	1.000	33309	0.863	∞	1.000	33350	0.864
	∞	40919	∞	1.000	42634	1.042	∞	1.000	42702	1.043
crossdock_15x8	∞	46540	∞	1.000	32094	0.690	∞	1.000	31972	0.688
	∞	38630	∞	1.000	35486	0.919	∞	1.000	35409	0.917
	∞	42033	∞	1.000	31070	0.740	∞	1.000	31797	0.757
crudeoil_lee1_05	1.65	5	1.64	0.996	5	1.000	1.63	0.992	5	1.000
	1.51	3	1.57	1.024	3	1.000	1.53	1.008	3	1.000
	2.65	8	2.57	0.978	8	1.000	2.58	0.981	8	1.000
crudeoil_lee1_06	1.67	52	1.61	0.978	50	0.987	1.60	0.974	50	0.987
	2.34	92	2.31	0.991	79	**0.932**	2.33	0.997	79	**0.932**
	2.25	38	2.26	1.003	38	1.000	2.27	1.006	38	1.000
crudeoil_lee1_07	4.32	20	4.17	0.972	20	1.000	4.20	0.977	20	1.000
	5.36	30	5.34	0.997	30	1.000	5.30	0.991	30	1.000
	2.71	82	2.66	0.987	76	0.967	2.61	0.973	76	0.967
crudeoil_lee1_08	4.53	97	4.49	0.993	89	0.959	4.54	1.002	89	0.959
	5.83	148	4.88	**0.861**	120	**0.887**	4.92	**0.867**	120	**0.887**
	4.59	71	4.44	0.973	71	1.000	4.48	0.980	71	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
crudeoil_lee1_09	8.51	102	7.16	**0.858**	112	1.050	7.24	**0.866**	115	*1.064*
	9.98	153	9.33	**0.941**	141	0.953	9.07	**0.917**	128	**0.901**
	9.94	153	10.08	1.013	105	**0.810**	10.06	1.011	100	**0.791**
crudeoil_lee1_10	8.01	187	7.96	0.994	187	1.000	7.90	0.988	188	1.003
	11.94	178	11.42	0.960	125	**0.809**	11.37	0.956	133	**0.838**
crudeoil_lee2_05	10.41	74	10.02	0.966	74	1.000	10.04	0.968	74	1.000
	15.08	5	15.03	0.997	5	1.000	15.01	0.996	5	1.000
	17.98	20	17.61	0.981	20	1.000	17.42	0.970	20	1.000
crudeoil_lee2_06	7.91	142	7.89	0.998	123	**0.921**	7.89	0.998	113	**0.880**
	18.80	311	17.54	**0.936**	169	**0.655**	17.59	**0.939**	169	**0.655**
	20.97	161	19.75	**0.944**	21	**0.464**	19.56	**0.936**	36	**0.521**
crudeoil_lee2_07	26.62	423	26.53	0.997	270	**0.707**	27.77	1.042	275	**0.717**
	29.27	275	28.51	0.975	223	**0.861**	28.60	0.978	223	**0.861**
	31.28	403	29.16	**0.934**	308	**0.811**	29.16	**0.934**	311	**0.817**
crudeoil_lee2_08	37.90	428	35.48	**0.938**	471	*1.081*	36.19	0.956	309	**0.775**
	41.08	464	39.82	0.970	293	**0.697**	39.85	0.971	342	**0.784**
	45.62	683	45.12	0.989	607	**0.903**	45.93	1.007	481	**0.742**
crudeoil_lee2_09	38.86	479	33.93	**0.876**	242	**0.591**	33.96	**0.877**	242	**0.591**
	34.77	631	35.92	1.032	553	**0.893**	33.70	0.970	526	**0.856**
	57.44	835	43.04	**0.754**	259	**0.384**	42.92	**0.752**	259	**0.384**
crudeoil_lee2_10	73.88	520	88.08	*1.190*	979	*1.740*	87.38	*1.180*	964	*1.716*
	69.09	409	64.43	**0.934**	415	1.012	64.26	**0.931**	406	0.994
	88.97	366	88.68	0.997	328	**0.918**	88.88	0.999	386	1.043
crudeoil_lee3_05	15.73	821	16.69	*1.057*	1351	*1.575*	16.66	*1.056*	1401	*1.630*
	26.68	1472	25.97	0.974	1972	*1.318*	26.31	0.987	1972	*1.318*
	18.51	2811	11.26	**0.628**	1161	**0.433**	11.32	**0.631**	1161	**0.433**
crudeoil_lee3_06	56.66	7232	53.12	**0.939**	4152	**0.580**	53.99	0.954	4322	**0.603**
	58.37	15001	50.45	**0.867**	10831	**0.724**	42.66	**0.735**	8841	**0.592**
crudeoil_lee3_07	111.59	24111	124.45	*1.114*	30391	*1.259*	133.63	*1.196*	31671	*1.312*
	49.47	7181	51.22	1.035	8121	*1.129*	62.90	*1.266*	13361	*1.849*
	83.15	15861	63.36	**0.765**	8831	**0.560**	75.26	**0.906**	13181	**0.832**
crudeoil_lee3_08	121.99	25921	87.80	**0.722**	13431	**0.520**	95.19	**0.782**	16341	**0.632**
	95.02	12911	82.92	**0.874**	13541	1.048	131.99	*1.385*	32911	*2.537*
	112.93	19883	122.24	*1.082*	20381	1.025	99.53	**0.882**	11991	**0.605**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
crudeoil_lee3_09	350.13	64951	198.00	**0.567**	29561	**0.456**	182.06	**0.521**	21861	**0.338**
	138.45	17821	169.62	*1.224*	32861	*1.839*	168.14	*1.213*	30791	*1.724*
	233.05	42631	123.37	**0.531**	9181	**0.217**	128.30	**0.552**	10811	**0.255**
crudeoil_lee3_10	212.39	33391	155.86	**0.735**	19631	**0.589**	145.77	**0.688**	13365	**0.402**
	259.28	31761	264.88	1.022	37431	*1.178*	264.06	1.018	32071	1.010
crudeoil_lee4_05	24.60	119	24.83	1.009	82	**0.831**	24.63	1.001	82	**0.831**
	11.85	52	11.70	0.988	88	*1.237*	11.69	0.988	88	*1.237*
	10.14	57	9.86	0.975	57	1.000	9.91	0.979	57	1.000
crudeoil_lee4_06	16.40	17	17.27	*1.050*	18	1.009	17.25	1.049	18	1.009
	20.84	212	21.18	1.016	106	**0.660**	21.30	1.021	106	**0.660**
	16.42	12	16.20	0.987	9	0.973	16.06	0.979	9	0.973
crudeoil_lee4_07	44.61	326	46.09	1.032	56	**0.366**	45.93	1.029	56	**0.366**
	26.57	196	26.09	0.983	8	**0.365**	26.06	0.982	8	**0.365**
	27.01	14	26.86	0.995	13	0.991	26.85	0.994	13	0.991
crudeoil_lee4_08	35.15	220	40.41	*1.146*	306	*1.269*	37.53	*1.066*	259	*1.122*
	36.57	145	34.29	**0.939**	22	**0.498**	34.30	**0.940**	22	**0.498**
	49.14	86	43.06	**0.879**	27	**0.683**	43.23	**0.882**	27	**0.683**
crudeoil_lee4_09	42.33	145	40.45	0.957	29	**0.527**	40.86	0.966	29	**0.527**
	51.79	11	51.98	1.004	11	1.000	52.16	1.007	11	1.000
	69.86	279	71.95	1.029	139	**0.631**	71.14	1.018	139	**0.631**
crudeoil_lee4_10	62.72	162	57.86	**0.924**	58	**0.603**	57.52	**0.918**	58	**0.603**
	100.81	51	100.41	0.996	21	**0.801**	100.16	0.994	21	**0.801**
	69.64	18	69.57	0.999	18	1.000	69.61	1.000	18	1.000
crudeoil_li01	0.32%	3374015	0.23%	1.000	3182383	0.943	0.42%	1.000	2739976	0.812
	0.40%	3441744	0.15%	1.000	3730750	1.084	0.16%	1.000	3100153	0.901
crudeoil_li02	1.13%	3640454	1.15%	1.000	3644347	1.001	1.15%	1.000	3641634	1.000
	1.15%	3597634	1.14%	1.000	3648778	1.014	1.14%	1.000	3628859	1.009
	1.14%	3722327	1.14%	1.000	3679411	0.988	1.13%	1.000	3760918	1.010
crudeoil_li03	1.86%	1147729	1.63%	1.000	921928	0.803	1.59%	1.000	1051715	0.916
	2.56%	932596	1.52%	1.000	963142	1.033	1.71%	1.000	1035844	1.111
	2.31%	1254294	1.85%	1.000	942504	0.751	1.78%	1.000	855260	0.682
crudeoil_li05	10.47%	1578334	9.12%	1.000	1165963	0.739	7.89%	1.000	1198426	0.759
	7.37%	1577838	8.82%	1.000	1124347	0.713	10.32%	1.000	1105582	0.701
	10.39%	1528726	6.69%	1.000	1325981	0.867	8.74%	1.000	1181594	0.773

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	5190.54	713256	340.72	**0.066**	25749	**0.036**	220.19	**0.043**	12794	**0.018**
crudeoil_li11	1.52%	1328436	1.32%	1.000	890734	0.671	1.36%	1.000	948655	0.714
	1.21%	1068181	1.38%	1.000	931315	0.872	1.09%	1.000	936215	0.876
	1.56%	1214546	1.45%	1.000	784653	0.646	1.53%	1.000	774997	0.638
crudeoil_li21	2.21%	921212	1.27%	1.000	766632	0.832	1.45%	1.000	777715	0.844
	2.24%	912240	1.42%	1.000	672707	0.737	1.76%	1.000	728836	0.799
	2.11%	755525	1.69%	1.000	663031	0.878	1.84%	1.000	670651	0.888
crudeoil_pooling_ct1	36.19%	984573	32.19%	1.000	899549	0.914	33.99%	1.000	861211	0.875
	37.11%	936780	32.67%	1.000	855436	0.913	32.71%	1.000	840047	0.897
crudeoil_pooling_ct2	0.53%	6135205	0.03%	1.000	4189108	0.683	0.43%	1.000	4845392	0.790
	0.05%	4842949	0.13%	1.000	3917810	0.809	0.32%	1.000	4497746	0.929
	0.56%	7139400	0.30%	1.000	4368439	0.612	0.32%	1.000	4755975	0.666
crudeoil_pooling_ct3	41.39%	469185	39.84%	1.000	466466	0.994	44.62%	1.000	412785	0.880
	56.84%	375517	50.12%	1.000	398690	1.062	47.61%	1.000	395386	1.053
	48.09%	441303	45.58%	1.000	338915	0.768	45.19%	1.000	386613	0.876
crudeoil_pooling_ct4	2.34%	4770692	2.37%	1.000	4684862	0.982	2.46%	1.000	4576038	0.959
	2.31%	4350995	2.44%	1.000	4514273	1.038	2.41%	1.000	4196784	0.965
	3.10%	4573711	3.14%	1.000	4218045	0.922	3.34%	1.000	4584848	1.002
crudeoil_pooling_dt1	441.21	5342	484.26	*1.097*	3991	**0.752**	480.96	*1.090*	4501	**0.845**
	948.35	29047	1261.86	*1.330*	53506	*1.839*	1166.27	*1.230*	50448	*1.734*
	492.17	7998	424.13	**0.862**	3655	**0.464**	424.55	**0.863**	3655	**0.464**
crudeoil_pooling_dt2	7.38%	252679	7.92%	1.000	192393	0.762	8.07%	1.000	223857	0.886
	11.73%	160388	10.12%	1.000	225956	1.409	10.86%	1.000	216476	1.349
	10.72%	188043	8.03%	1.000	221634	1.179	7.10%	1.000	234946	1.249
crudeoil_pooling_dt3	4.43%	469413	1556.74	**0.216**	14717	**0.032**	1565.83	**0.218**	14735	**0.032**
	3960.90	137179	2081.53	**0.526**	24318	**0.178**	2080.67	**0.525**	24318	**0.178**
	2121.15	27711	3065.39	*1.445*	83541	*3.007*	3511.96	*1.655*	100221	*3.607*
crudeoil_pooling_dt4	8.11%	392086	8.10%	1.000	280858	0.716	8.10%	1.000	272314	0.695
	8.13%	207523	8.09%	1.000	244006	1.176	8.10%	1.000	226520	1.091
	8.18%	253558	8.19%	1.000	256317	1.011	8.11%	1.000	181258	0.715
csched2	821.26%	571518	836.39%	1.000	114356	0.200	831.63%	1.000	274260	0.480
	839.69%	497	811.08%	1.000	988342	1655.682	806.80%	1.000	1553183	2601.814
cvxnonsep_normcon20	1.07	5	1.09	1.010	5	1.000	1.08	1.005	5	1.000
	1.10	5	1.10	1.000	5	1.000	1.08	0.990	5	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1.09	5	1.10	1.005	5	1.000	1.06	0.986	5	1.000
cvxnonsep_normcon20r	0.50	24	0.50	1.000	24	1.000	0.50	1.000	24	1.000
	0.50	24	0.50	1.000	24	1.000	0.50	1.000	24	1.000
	0.50	24	0.50	1.000	24	1.000	0.50	1.000	24	1.000
cvxnonsep_normcon30	4.49	354	4.74	1.046	376	1.048	4.78	*1.053*	376	1.048
	4.55	354	4.73	1.032	376	1.048	4.90	*1.063*	376	1.048
	4.57	354	4.82	1.045	376	1.048	4.81	1.043	376	1.048
cvxnonsep_normcon30r	0.59	49	0.61	1.013	56	1.047	0.60	1.006	56	1.047
	0.62	49	0.61	0.994	56	1.047	0.63	1.006	56	1.047
	0.57	49	0.62	1.032	56	1.047	0.64	1.045	56	1.047
cvxnonsep_normcon40	32.00	9564	32.82	1.025	7675	**0.805**	33.20	1.036	7675	**0.805**
	32.08	9564	32.95	1.026	7675	**0.805**	33.05	1.029	7675	**0.805**
	32.06	9564	32.82	1.023	7675	**0.805**	32.80	1.022	7675	**0.805**
cvxnonsep_normcon40r	0.69	57	0.75	1.036	79	*1.140*	0.75	1.036	79	*1.140*
	0.71	57	0.72	1.006	79	*1.140*	0.73	1.012	79	*1.140*
	0.70	57	0.78	1.047	79	*1.140*	0.76	1.035	79	*1.140*
cvxnonsep_nsig20	1.30%	755263	3.61%	1.000	42918	0.057	3.61%	1.000	42918	0.057
	1.28%	759792	3.61%	1.000	42918	0.057	3.61%	1.000	42918	0.057
	1.28%	760253	3.61%	1.000	42918	0.057	3.61%	1.000	42918	0.057
cvxnonsep_nsig20r	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
cvxnonsep_nsig30	6.15%	329471	5.68%	1.000	304528	0.924	5.67%	1.000	307560	0.934
	6.15%	327651	5.68%	1.000	304720	0.930	5.67%	1.000	309524	0.945
	6.15%	329372	5.68%	1.000	303019	0.920	5.67%	1.000	309890	0.941
cvxnonsep_nsig30r	0.50	41	0.50	1.000	51	*1.071*	0.50	1.000	51	*1.071*
	0.50	41	0.50	1.000	51	*1.071*	0.50	1.000	51	*1.071*
	0.50	41	0.50	1.000	51	*1.071*	0.50	1.000	51	*1.071*
cvxnonsep_nsig40	16.84%	228	16.84%	1.000	228	1.000	16.84%	1.000	228	1.000
	16.84%	228	16.84%	1.000	228	1.000	16.84%	1.000	228	1.000
	16.84%	228	16.84%	1.000	228	1.000	16.84%	1.000	228	1.000
cvxnonsep_nsig40r	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
cvxnonsep_pcon20	0.50	48	0.50	1.000	48	1.000	0.50	1.000	48	1.000
	0.50	48	0.50	1.000	48	1.000	0.50	1.000	48	1.000
	0.50	48	0.50	1.000	48	1.000	0.50	1.000	48	1.000
cvxnonsep_pcon20r	0.50	26	0.50	1.000	26	1.000	0.50	1.000	26	1.000
	0.50	26	0.50	1.000	26	1.000	0.50	1.000	26	1.000
	0.50	26	0.50	1.000	26	1.000	0.50	1.000	26	1.000
cvxnonsep_pcon30	0.50	63	0.50	1.000	59	0.975	0.50	1.000	59	0.975
	0.50	63	0.50	1.000	59	0.975	0.50	1.000	59	0.975
	0.50	63	0.50	1.000	59	0.975	0.50	1.000	59	0.975
cvxnonsep_pcon30r	0.64	104	0.66	1.012	104	1.000	0.63	0.994	104	1.000
	0.82	132	0.70	**0.934**	137	1.022	0.72	**0.945**	137	1.022
cvxnonsep_pcon40	0.50	82	0.56	1.040	78	0.978	0.54	1.027	78	0.978
	0.50	82	0.53	1.020	78	0.978	0.58	*1.053*	78	0.978
	0.53	82	0.52	0.993	78	0.978	0.52	0.993	78	0.978
cvxnonsep_pcon40r	0.51	30	0.50	0.993	30	1.000	0.50	0.993	30	1.000
	0.84	178	0.87	1.016	177	0.996	0.86	1.011	177	0.996
	0.50	22	0.51	1.007	22	1.000	0.50	1.000	22	1.000
cvxnonsep_psig20	7.91	2311	6.60	**0.853**	1426	**0.633**	6.55	**0.847**	1426	**0.633**
	7.74	2311	6.62	**0.872**	1426	**0.633**	6.63	**0.873**	1426	**0.633**
	7.80	2311	6.69	**0.874**	1426	**0.633**	6.62	**0.866**	1426	**0.633**
cvxnonsep_psig20r	0.50	6	0.50	1.000	6	1.000	0.50	1.000	6	1.000
	0.50	6	0.50	1.000	6	1.000	0.50	1.000	6	1.000
	0.50	6	0.50	1.000	6	1.000	0.50	1.000	6	1.000
cvxnonsep_psig30	2.81%	851436	5.00%	1.000	373289	0.438	5.01%	1.000	374194	0.440
	2.81%	852728	5.00%	1.000	372455	0.437	5.02%	1.000	371969	0.436
	2.82%	847651	5.00%	1.000	372555	0.440	5.02%	1.000	371254	0.438
cvxnonsep_psig30r	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
cvxnonsep_psig40	3.80%	253151	3.07%	1.000	199854	0.790	3.07%	1.000	200250	0.791
	3.80%	252895	3.07%	1.000	199854	0.790	3.06%	1.000	201564	0.797
	3.79%	254153	3.07%	1.000	199433	0.785	3.07%	1.000	199365	0.785
cvxnonsep_psig40r	0.59	85	0.63	1.025	85	1.000	0.65	1.038	85	1.000
	0.59	85	0.63	1.025	85	1.000	0.62	1.019	85	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.62	85	0.63	1.006	85	1.000	0.64	1.012	85	1.000
densitymod	∞	4310	∞	1.000	3400	0.794	∞	1.000	3435	0.802
	∞	4366	∞	1.000	4692	1.073	∞	1.000	4733	1.082
	∞	1833	∞	1.000	1055	0.598	∞	1.000	1171	0.658
du-opt5	0.53	54	0.55	1.013	61	1.045	0.53	1.000	61	1.045
	0.55	54	0.56	1.006	61	1.045	0.55	1.000	61	1.045
	0.57	54	0.52	0.968	61	1.045	0.55	0.987	61	1.045
du-opt	11.60	12715	12.26	*1.052*	11697	**0.921**	12.13	1.042	11697	**0.921**
	13.22	14279	12.83	0.973	12519	**0.878**	12.79	0.970	12519	**0.878**
	11.51	12715	12.21	*1.056*	11697	**0.921**	12.23	*1.058*	11697	**0.921**
edgecross10-010	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
edgecross10-020	1.20	270	1.63	*1.195*	337	*1.181*	1.68	*1.218*	337	*1.181*
	0.81	142	0.77	0.978	97	**0.814**	0.75	0.967	97	**0.814**
	1.14	135	1.22	1.037	93	**0.821**	1.23	1.042	93	**0.821**
edgecross10-030	1.99	775	1.99	1.000	650	**0.857**	1.99	1.000	650	**0.857**
	2.97	1097	2.60	**0.907**	1032	**0.946**	2.65	**0.919**	1032	**0.946**
	1.65	730	1.36	**0.891**	726	0.995	1.40	**0.906**	726	0.995
edgecross10-040	8.01	1956	6.62	**0.846**	1640	**0.846**	6.57	**0.840**	1640	**0.846**
	6.54	1681	5.97	**0.924**	1631	0.972	5.98	**0.926**	1631	0.972
	6.88	1749	6.56	0.959	1814	1.035	6.54	0.957	1814	1.035
edgecross10-050	16.94	3537	23.44	*1.362*	4293	*1.208*	23.39	*1.360*	4293	*1.208*
	25.69	4448	30.24	*1.170*	5526	*1.237*	30.34	*1.174*	5526	*1.237*
	56.95	17193	49.02	**0.863**	13244	**0.772**	48.95	**0.862**	13244	**0.772**
edgecross10-060	517.29	4769	515.82	0.997	4769	1.000	516.95	0.999	4769	1.000
	458.70	4881	458.60	1.000	4881	1.000	461.46	1.006	4881	1.000
	467.61	5019	467.61	1.000	5019	1.000	468.15	1.001	5019	1.000
edgecross10-070	236.82	127172	238.13	1.006	141806	*1.115*	238.26	1.006	141806	*1.115*
	1333.47	1236422	1095.21	**0.821**	911483	**0.737**	1091.80	**0.819**	911483	**0.737**
	209.76	138184	140.43	**0.671**	90311	**0.654**	140.91	**0.673**	90311	**0.654**
edgecross10-080	148.07	13507	149.80	1.012	13614	1.008	150.01	1.013	13614	1.008
	204.81	17820	201.72	0.985	17410	0.977	201.63	0.985	17410	0.977
	188.61	16635	186.42	0.988	14933	**0.898**	187.13	0.992	14933	**0.898**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
edgecross10-090	3.37	915	2.71	**0.849**	770	**0.857**	2.65	**0.835**	770	**0.857**
	1.43	488	1.37	0.975	418	**0.881**	1.39	0.984	418	**0.881**
	1.86	278	1.89	1.010	296	1.048	1.93	1.024	296	1.048
edgecross14-019	2.33	296	2.04	**0.913**	223	**0.816**	2.01	**0.904**	223	**0.816**
	1.16	129	1.24	1.037	90	**0.830**	1.30	*1.065*	90	**0.830**
	0.99	99	1.03	1.020	103	1.020	0.98	0.995	103	1.020
edgecross14-039	4341.15	4155	4335.88	0.999	4155	1.000	4365.45	1.006	4135	0.995
	1934.04	1944	1932.31	0.999	1944	1.000	1935.15	1.001	1944	1.000
	1590.19	1568	1610.02	1.012	1568	1.000	1592.15	1.001	1568	1.000
edgecross14-058	581.36	291958	611.12	*1.051*	300039	1.028	611.30	*1.051*	300039	1.028
	266.06	104794	247.29	**0.930**	88497	**0.845**	248.83	**0.935**	88497	**0.845**
	5808.54	4327580	1064.61	**0.183**	607145	**0.140**	1073.68	**0.185**	607145	**0.140**
edgecross14-078	24.27%	115521	25.53%	1.000	110534	0.957	25.55%	1.000	110293	0.955
	22.79%	124591	22.26%	1.000	126203	1.013	22.33%	1.000	125644	1.008
	22.96%	122887	24.41%	1.000	117076	0.953	24.33%	1.000	118035	0.961
edgecross14-098	20.59%	5329722	17.90%	1.000	5060707	0.950	17.89%	1.000	5065342	0.950
	25.82%	5087295	26.64%	1.000	4716185	0.927	26.64%	1.000	4716447	0.927
	36.09%	4287395	19.62%	1.000	4642231	1.083	19.60%	1.000	4654867	1.086
edgecross14-117	9.76%	5531429	12.12%	1.000	4966488	0.898	12.13%	1.000	4965554	0.898
	26.06%	3837290	17.64%	1.000	4566615	1.190	17.64%	1.000	4564185	1.189
	21.28%	4336493	17.34%	1.000	4739834	1.093	17.36%	1.000	4722374	1.089
edgecross14-137	9.99%	2782991	7.51%	1.000	2863847	1.029	7.54%	1.000	2852441	1.025
	6.41%	3193505	5717.29	**0.794**	1992360	**0.624**	5711.08	**0.793**	1992360	**0.624**
	7190.64	3144912	5840.82	**0.812**	2630592	**0.836**	5829.24	**0.811**	2630592	**0.836**
edgecross14-156	19.58%	13319	18.79%	1.000	18015	1.350	19.15%	1.000	13632	1.023
	19.80%	14546	20.48%	1.000	19122	1.312	20.83%	1.000	16443	1.130
	19.31%	13894	19.86%	1.000	18613	1.337	19.74%	1.000	13429	0.967
edgecross14-176	743.39	237754	695.11	**0.935**	229531	0.965	692.11	**0.931**	229531	0.965
	582.89	186746	581.60	0.998	193451	1.036	581.84	0.998	193451	1.036
	667.10	213780	689.95	1.034	241312	*1.129*	691.01	1.036	241312	*1.129*
edgecross20-040	468.62	36563	570.92	*1.218*	38435	*1.051*	570.40	*1.217*	38435	*1.051*
	421.75	28481	417.69	0.990	26781	**0.941**	417.36	0.990	26781	**0.941**
	425.59	30283	436.67	1.026	31330	1.034	435.95	1.024	31330	1.034
edgecross20-080	139.66%	632342	135.19%	1.000	661824	1.047	135.29%	1.000	659975	1.044

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	136.74%	517874	140.36%	1.000	603343	1.165	140.35%	1.000	603455	1.165
	177.59%	519766	150.65%	1.000	492198	0.947	150.93%	1.000	489171	0.941
edgecross22-048	3191.29	193582	2401.56	**0.753**	133871	**0.692**	2408.14	**0.755**	133871	**0.692**
	3983.46	279043	3866.43	0.971	238102	**0.853**	3856.90	0.968	238102	**0.853**
	2527.53	142483	2794.83	*1.106*	173577	*1.218*	2791.99	*1.105*	173577	*1.218*
edgecross22-096	306.42%	270582	268.80%	1.000	253141	0.936	269.53%	1.000	251198	0.928
	232.36%	241083	243.10%	1.000	258248	1.071	243.33%	1.000	257421	1.068
	393.75%	241073	224.48%	1.000	245555	1.019	224.40%	1.000	245816	1.020
edgecross24-057	187.88%	327021	132.04%	1.000	435863	1.333	131.98%	1.000	436117	1.334
	223.16%	274972	259.38%	1.000	279412	1.016	259.11%	1.000	280044	1.018
	252.59%	328704	239.21%	1.000	335724	1.021	239.12%	1.000	336154	1.023
edgecross24-115	748.63%	174152	692.91%	1.000	121231	0.696	693.14%	1.000	121015	0.695
	577.37%	159553	567.63%	1.000	120339	0.754	567.63%	1.000	120297	0.754
	530.93%	113497	524.43%	1.000	145198	1.279	524.38%	1.000	145256	1.280
eg_all_s	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
eg_disc2_s	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
eg_disc_s	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
eg_int_s	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
elf	0.91	278	0.89	0.990	256	**0.942**	0.86	0.974	256	**0.942**
	0.84	275	0.81	0.984	275	1.000	0.83	0.995	275	1.000
	0.50	275	0.50	1.000	194	**0.784**	0.50	1.000	194	**0.784**
eniplac	1.97	34	2.02	1.017	34	1.000	1.94	0.990	34	1.000
	3.84	3	3.81	0.994	3	1.000	3.84	1.000	3	1.000
	2.05	3	2.15	1.033	3	1.000	2.12	1.023	3	1.000
enpro48pb	2.83	9	2.98	1.039	13	1.037	2.88	1.013	13	1.037
	3.06	60	2.73	**0.919**	34	**0.838**	2.65	**0.899**	34	**0.838**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	2.57	88	2.07	**0.860**	37	**0.729**	2.15	**0.882**	37	**0.729**
enpro56pb	6.81	180	6.26	**0.930**	105	**0.732**	6.22	**0.924**	105	**0.732**
	5.82	166	5.75	0.990	164	0.992	5.79	0.996	164	0.992
	6.60	74	6.40	0.974	67	0.960	6.30	0.961	67	0.960
ethanolh	155.23%	1079145	155.31%	1.000	1075823	0.997	192.62%	1.000	1684908	1.561
	79.88%	1460444	78.24%	1.000	1499001	1.026	80.20%	1.000	1552584	1.063
	333.70%	821	333.70%	1.000	821	1.000	333.70%	1.000	821	1.000
ethanolm	33.75%	1505181	34.14%	1.000	1476056	0.981	31.20%	1.000	1531559	1.018
	25.32%	1697463	23.59%	1.000	1683874	0.992	22.67%	1.000	1701128	1.002
	40.49%	1744785	37.47%	1.000	1741282	0.998	41.86%	1.000	1723503	0.988
ex1221	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1222	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1223	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
ex1223a	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1223b	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
ex1224	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1225	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1226	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
ex1233	62.21%	100	62.21%	1.000	100	1.000	62.21%	1.000	100	1.000
	0.36%	16235630	0.38%	1.000	8635064	0.532	0.36%	1.000	12919571	0.796
	1.18%	18982979	1.06%	1.000	14121501	0.744	1.00%	1.000	13949161	0.735
ex1243	3.40	551	3.40	1.000	551	1.000	3.44	1.009	551	1.000
	2.12	243	2.10	0.994	243	1.000	2.07	0.984	243	1.000
	3.43	594	3.38	0.989	594	1.000	3.40	0.993	594	1.000
ex1244	15.59	11571	15.60	1.001	11571	1.000	15.56	0.998	11571	1.000
	9.84	1873	9.62	0.980	1655	**0.890**	9.53	0.971	1655	**0.890**
ex1252	4.18	1328	4.19	1.002	1328	1.000	4.08	0.981	1328	1.000
	7.54	1341	7.60	1.007	1341	1.000	7.39	0.982	1349	1.006
ex1252a	11.05	1633	10.94	0.991	1633	1.000	10.97	0.993	1633	1.000
	7.25	1510	7.28	1.004	1510	1.000	7.17	0.990	1510	1.000
	5.75	1368	5.89	1.021	1368	1.000	5.98	1.034	1368	1.000
ex1263	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
ex1263a	0.50	56	0.50	1.000	57	1.006	0.50	1.000	57	1.006
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
ex1264	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1264a	0.50	13	0.50	1.000	13	1.000	0.50	1.000	13	1.000
	0.50	17	0.50	1.000	17	1.000	0.50	1.000	17	1.000
	0.50	15	0.50	1.000	15	1.000	0.50	1.000	15	1.000
ex1265	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1265a	0.50	59	0.50	1.000	54	0.969	0.50	1.000	54	0.969
	0.50	13	0.50	1.000	13	1.000	0.50	1.000	13	1.000
	0.50	55	0.50	1.000	51	0.974	0.50	1.000	51	0.974
ex1266	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
ex1266a	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	31	0.50	1.000	26	0.962	0.50	1.000	26	0.962
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex4	3.08	15	3.12	1.010	15	1.000	3.15	1.017	15	1.000
	3.61	5	3.66	1.011	5	1.000	3.64	1.007	5	1.000
	2.70	11	2.75	1.014	11	1.000	2.73	1.008	11	1.000
fac1	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
fac2	26.69	50356	20.42	**0.774**	39182	**0.779**	20.38	**0.772**	39182	**0.779**
	0.93	2	0.96	1.016	2	1.000	0.96	1.016	2	1.000
	0.95	4	0.93	0.990	4	1.000	0.93	0.990	4	1.000
fac3	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	6	0.50	1.000	6	1.000	0.50	1.000	6	1.000
	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
faclay20h	63.83%	99386	64.60%	1.000	95483	0.961	64.60%	1.000	95484	0.961
	51.83%	94276	52.33%	1.000	95795	1.016	52.38%	1.000	95441	1.012
	53.56%	98286	55.47%	1.000	99916	1.017	55.54%	1.000	99206	1.009
faclay25	170.28%	179414	177.36%	1.000	198399	1.106	177.36%	1.000	198385	1.106
	175.47%	195393	171.32%	1.000	155301	0.795	171.33%	1.000	155077	0.794
	132.33%	410625	131.42%	1.000	363228	0.885	131.76%	1.000	356698	0.869
faclay30	248.43%	140309	232.55%	1.000	87670	0.625	232.91%	1.000	87241	0.622
	283.25%	87871	279.31%	1.000	62027	0.706	279.39%	1.000	61731	0.703
	255.36%	97158	263.47%	1.000	23621	0.244	263.49%	1.000	23620	0.244
faclay30h	265.15%	3080	274.16%	1.000	3171	1.029	273.92%	1.000	3181	1.032
	281.34%	13047	275.52%	1.000	12262	0.940	275.55%	1.000	12247	0.939
	388.09%	3163	412.53%	1.000	10044	3.109	400.47%	1.000	11238	3.475
faclay33	414.86%	1227	366.51%	1.000	4324	3.334	366.51%	1.000	4323	3.333
	392.98%	4003	402.80%	1.000	4052	1.012	402.84%	1.000	4012	1.002
	388.64%	3774	395.25%	1.000	3698	0.980	395.25%	1.000	3694	0.979
faclay35	604.93%	1538	534.59%	1.000	6817	4.223	584.25%	1.000	4489	2.802
	495.96%	6732	467.07%	1.000	6404	0.952	464.85%	1.000	6489	0.964
	596.82%	6961	552.76%	1.000	6513	0.937	552.76%	1.000	6503	0.935
faclay60	1848.00%	6	1848.00%	1.000	6	1.000	1848.00%	1.000	6	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1846.42%	4	1846.42%	1.000	4	1.000	1846.42%	1.000	4	1.000
	1848.57%	7	1848.57%	1.000	7	1.000	1848.57%	1.000	7	1.000
faclay70	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	2934.38%	1	2934.38%	1.000	1	1.000	2934.38%	1.000	1	1.000
	2781.44%	1	2781.44%	1.000	1	1.000	2781.44%	1.000	1	1.000
faclay75	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
faclay80	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
feedtray2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
feedtray	784.35%	27136	465.95%	1.000	23736	0.875	459.45%	1.000	22131	0.816
	465.95%	46465	465.95%	1.000	48680	1.048	465.95%	1.000	77183	1.660
	459.45%	10480	459.45%	1.000	8779	0.839	459.45%	1.000	5062	0.488
fin2bb	18.33	51	18.29	0.998	51	1.000	18.32	0.999	51	1.000
	56.20	300	201.96	*3.548*	4800	*12.250*	78.05	*1.382*	300	1.000
	111.06	5740	75.13	**0.679**	790	**0.152**	97.46	**0.879**	1940	**0.349**
flay02h	1.92	7	1.96	1.014	7	1.000	1.91	0.997	7	1.000
	1.54	7	1.55	1.004	7	1.000	1.53	0.996	7	1.000
	1.37	7	1.41	1.017	7	1.000	1.37	1.000	7	1.000
flay02m	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.64	7	0.63	0.994	7	1.000	0.62	0.988	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
flay03h	3.61	102	3.65	1.009	102	1.000	3.63	1.004	102	1.000
	3.24	111	3.22	0.995	111	1.000	3.22	0.995	111	1.000
	3.46	112	3.49	1.007	112	1.000	3.44	0.996	112	1.000
flay03m	1.68	103	1.68	1.000	103	1.000	1.64	0.985	103	1.000
	1.17	103	1.15	0.991	103	1.000	1.16	0.995	103	1.000
	1.35	105	1.38	1.013	105	1.000	1.37	1.009	105	1.000
flay04h	7.29	2027	7.48	1.023	2075	1.023	7.57	1.034	2075	1.023
	8.22	2063	8.20	0.998	2159	1.044	8.24	1.002	2159	1.044

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	7.20	2159	7.94	*1.090*	2193	1.015	7.90	*1.085*	2193	1.015
flay04m	3.32	1825	3.27	0.988	1849	1.012	3.27	0.988	1849	1.012
	3.53	1939	3.56	1.007	2042	*1.051*	3.54	1.002	2042	*1.051*
	3.09	1943	3.22	1.032	1949	1.003	3.21	1.029	1949	1.003
flay05h	160.94	90925	166.82	1.036	92281	1.015	168.47	1.046	92075	1.013
	157.91	91358	158.07	1.001	90556	0.991	157.48	0.997	90510	0.991
	158.30	92763	155.31	0.981	87982	**0.949**	156.20	0.987	87614	**0.945**
flay05m	50.40	70558	52.16	1.034	68868	0.976	52.45	1.040	68868	0.976
	55.94	78017	53.31	0.954	72578	**0.930**	53.16	0.951	72578	**0.930**
	50.70	72731	52.16	1.028	69430	0.955	52.32	1.031	69430	0.955
flay06h	3.27%	4120321	3.71%	1.000	4062096	0.986	3.69%	1.000	4011062	0.973
	3.68%	4195096	3.71%	1.000	4113926	0.981	3.74%	1.000	4056434	0.967
	3.77%	3959672	3.77%	1.000	3961523	1.000	3.77%	1.000	3883895	0.981
flay06m	1813.53	3033105	1887.75	1.041	3062342	1.010	1881.52	1.037	3065438	1.011
	1916.53	3080877	1788.18	**0.933**	2843589	**0.923**	1799.21	**0.939**	2860990	**0.929**
	2384.13	3583282	1995.36	**0.837**	3064705	**0.855**	2004.32	**0.841**	3054560	**0.852**
fo7	72.88	111085	73.84	1.013	81298	**0.732**	75.99	1.042	81663	**0.735**
	176.00	268833	79.06	**0.452**	110781	**0.412**	79.21	**0.453**	110781	**0.412**
	100.09	134645	71.77	**0.720**	91155	**0.677**	71.70	**0.719**	91155	**0.677**
fo7_2	31.20	30959	32.46	1.039	32575	*1.052*	32.51	1.041	32575	*1.052*
	64.35	70170	41.54	**0.651**	40838	**0.583**	41.40	**0.649**	40838	**0.583**
	67.60	79711	53.76	**0.798**	57713	**0.724**	53.44	**0.794**	57713	**0.724**
fo7_ar25_1	27.07	42487	17.71	**0.667**	22415	**0.529**	17.83	**0.671**	22415	**0.529**
	40.06	52101	25.83	**0.653**	32407	**0.623**	26.47	**0.669**	33216	**0.638**
	16.21	19334	17.32	*1.064*	19782	1.023	17.19	*1.057*	19781	1.023
fo7_ar2_1	26.35	35861	16.50	**0.640**	20219	**0.565**	16.48	**0.639**	20219	**0.565**
	27.19	36527	32.96	*1.205*	47234	*1.292*	29.47	*1.081*	45976	*1.258*
	31.26	46261	31.58	1.010	46929	1.014	31.28	1.001	47000	1.016
fo7_ar3_1	37.48	52615	33.98	**0.909**	42706	**0.812**	34.67	**0.927**	41625	**0.792**
	55.53	77778	43.54	**0.788**	62641	**0.806**	42.40	**0.768**	61916	**0.796**
	58.76	88997	39.18	**0.672**	55876	**0.628**	39.34	**0.675**	55876	**0.628**
fo7_ar4_1	69.93	99646	79.08	*1.129*	97040	0.974	79.55	*1.136*	97040	0.974
	51.70	67908	43.53	**0.845**	59319	**0.874**	44.32	**0.860**	59132	**0.871**
	68.43	91779	44.73	**0.659**	54722	**0.597**	44.31	**0.653**	55599	**0.606**

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Table E.2: Detailed computational results on nonconvex instances of MINLPLIB.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
fo7_ar5_1	32.20	38340	21.34	**0.673**	22092	**0.577**	22.39	**0.705**	22592	**0.590**
	23.85	27827	18.95	**0.803**	22660	**0.815**	18.88	**0.800**	22660	**0.815**
	21.85	21815	25.77	*1.172*	27520	*1.260*	27.57	*1.250*	28145	*1.289*
fo8	484.24	770027	163.30	**0.339**	198949	**0.258**	175.28	**0.363**	225847	**0.293**
	233.54	308889	128.88	**0.554**	176270	**0.571**	128.73	**0.553**	176211	**0.571**
	100.46	133263	59.33	**0.595**	62056	**0.466**	58.56	**0.587**	62056	**0.466**
fo8_ar25_1	243.84	416948	168.84	**0.694**	278321	**0.668**	190.07	**0.780**	312392	**0.749**
	212.79	391313	148.72	**0.700**	267562	**0.684**	154.65	**0.728**	279558	**0.714**
	240.47	428064	154.96	**0.646**	249676	**0.583**	153.29	**0.639**	253886	**0.593**
fo8_ar2_1	181.61	370226	140.98	**0.778**	274418	**0.741**	131.39	**0.725**	257126	**0.695**
	151.82	284759	141.58	**0.933**	274949	0.966	125.56	**0.828**	244221	**0.858**
	127.81	240028	149.87	*1.171*	286475	*1.193*	141.84	*1.109*	280950	*1.170*
fo8_ar3_1	84.50	96319	37.23	**0.447**	33245	**0.346**	36.56	**0.439**	32907	**0.342**
	76.04	110915	29.78	**0.400**	36352	**0.328**	29.74	**0.399**	37086	**0.335**
	34.36	32478	33.37	0.972	36197	*1.114*	34.03	0.991	34632	*1.066*
fo8_ar4_1	130.05	187088	112.31	**0.865**	160678	**0.859**	111.74	**0.860**	159301	**0.852**
	98.49	130212	40.32	**0.415**	38822	**0.299**	39.35	**0.406**	39991	**0.308**
	74.96	99417	84.72	*1.128*	116753	*1.174*	84.11	*1.120*	112345	*1.130*
fo8_ar5_1	222.17	351697	103.96	**0.470**	146264	**0.416**	88.95	**0.403**	119830	**0.341**
	245.90	369577	109.59	**0.448**	154677	**0.419**	135.63	**0.553**	202180	**0.547**
	209.89	299992	139.26	**0.665**	199354	**0.665**	153.06	**0.731**	213411	**0.711**
fo9	840.34	1219849	683.55	**0.814**	969543	**0.795**	763.92	**0.909**	1026389	**0.841**
	1156.15	1681207	486.53	**0.421**	753623	**0.448**	524.37	**0.454**	809908	**0.482**
fo9_ar25_1	3150.98	5400537	3188.23	1.012	5196800	0.962	3469.78	*1.101*	5708897	*1.057*
	4270.66	6353464	4082.44	0.956	5909450	**0.930**	3919.48	**0.918**	6015226	**0.947**
	4382.88	6964783	3663.53	**0.836**	5973269	**0.858**	3881.74	**0.886**	6116570	**0.878**
fo9_ar2_1	1759.43	2849398	1107.47	**0.630**	1916407	**0.673**	1191.81	**0.678**	1990249	**0.698**
	1762.32	2753859	987.08	**0.560**	1703367	**0.619**	786.47	**0.447**	1290894	**0.469**
	1487.45	2584428	1542.73	1.037	2739448	*1.060*	1219.01	**0.820**	2215192	**0.857**
fo9_ar3_1	290.56	397690	35.49	**0.125**	36484	**0.092**	35.26	**0.124**	35429	**0.089**
	59.59	55540	60.76	1.019	72881	*1.312*	60.98	1.023	74272	*1.337*
	373.07	428449	140.30	**0.378**	160574	**0.375**	149.12	**0.401**	156011	**0.364**
fo9_ar4_1	778.81	1094487	144.65	**0.187**	177266	**0.162**	176.53	**0.228**	210572	**0.192**
	637.01	766506	589.02	**0.925**	815958	*1.065*	286.71	**0.451**	431387	**0.563**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
fo9_ar5_1	1163.42	1390307	406.75	**0.350**	506954	**0.365**	266.19	**0.229**	353235	**0.254**
	1172.70	1534693	512.75	**0.438**	700738	**0.457**	575.02	**0.491**	787555	**0.513**
	1432.20	1838362	782.71	**0.547**	1010648	**0.550**	975.78	**0.682**	1204213	**0.655**
forest	41.82%	279	41.82%	1.000	279	1.000	41.82%	1.000	279	1.000
	37.18%	179328	37.18%	1.000	179328	1.000	37.35%	1.000	13859	0.078
	46.99%	3563	46.99%	1.000	3563	1.000	46.99%	1.000	2037	0.583
fuel	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
fuzzy	31.05%	93143	1.32%	1.000	153625	1.649	1.33%	1.000	90547	0.972
	161.92%	148846	107.35%	1.000	123575	0.830	17.76%	1.000	89323	0.600
	112.30%	264968	67.79%	1.000	291101	1.099	42.57%	1.000	319601	1.206
gabriel01	1639.27	1064655	1338.69	**0.817**	907213	**0.852**	1412.38	**0.862**	808217	**0.759**
	1460.13	883835	963.61	**0.660**	580069	**0.656**	1676.55	*1.148*	1044212	*1.181*
	1261.23	823355	1601.18	*1.269*	1035369	*1.257*	3147.09	*2.494*	2041223	*2.479*
gabriel02	20.75%	2811181	24.29%	1.000	3181170	1.132	24.79%	1.000	3172624	1.129
	24.60%	3575768	24.19%	1.000	3478488	0.973	12.20%	1.000	3373028	0.943
	24.01%	2654329	24.05%	1.000	2525686	0.952	23.40%	1.000	2604573	0.981
gabriel04	1380.54	364531	3722.31	*2.695*	1244199	*3.412*	1849.63	*1.340*	580333	*1.592*
	1917.11	534196	3038.36	*1.585*	1007034	*1.885*	2293.08	*1.196*	661820	*1.239*
	2334.23	623500	1878.55	**0.805**	498865	**0.800**	1561.94	**0.669**	391946	**0.629**
gabriel05	∞	1339390	∞	1.000	1294562	0.967	∞	1.000	1232327	0.920
	∞	1319363	∞	1.000	1286070	0.975	∞	1.000	1143090	0.866
	∞	1177014	∞	1.000	1163958	0.989	∞	1.000	1243442	1.056
gabriel06	∞	410602	∞	1.000	377144	0.919	∞	1.000	385217	0.938
	∞	350053	∞	1.000	355855	1.017	∞	1.000	373579	1.067
	∞	356183	∞	1.000	403162	1.132	∞	1.000	375578	1.054
gabriel07	∞	280757	∞	1.000	284999	1.015	∞	1.000	307260	1.094
	∞	274882	∞	1.000	231035	0.841	∞	1.000	243282	0.885
	∞	250709	∞	1.000	266231	1.062	∞	1.000	296533	1.183
gabriel08	∞	9583	∞	1.000	4754	0.501	∞	1.000	3871	0.410
	∞	11195	∞	1.000	4469	0.405	∞	1.000	6090	0.548
	∞	12879	∞	1.000	12453	0.967	∞	1.000	10474	0.815
gabriel09	19.02%	375880	19.06%	1.000	434335	1.155	18.88%	1.000	423272	1.126

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	19.42%	421243	19.55%	1.000	437214	1.038	19.19%	1.000	437194	1.038
	21.71%	432595	22.25%	1.000	472365	1.092	21.52%	1.000	421567	0.975
gabriel10	2095.01%	1	2095.01%	1.000	1	1.000	2095.01%	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
gams01	4520.52%	215624	4470.27%	1.000	259833	1.205	4472.69%	1.000	254252	1.179
	4470.27%	283975	4443.66%	1.000	294765	1.038	4917.46%	1.000	276195	0.973
	4890.32%	107970	5525.86%	1.000	126011	1.167	4443.66%	1.000	127021	1.176
gams02	333.23%	48752	333.23%	1.000	48752	1.000	327.43%	1.000	20678	0.425
	312.81%	22236	312.81%	1.000	22236	1.000	292.62%	1.000	28462	1.279
	282.29%	34297	282.29%	1.000	34297	1.000	282.65%	1.000	46015	1.341
gams03	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	9794.65%	34	9794.65%	1.000	34	1.000	9794.65%	1.000	34	1.000
gasnet	∞	48448	∞	1.000	51759	1.068	82.27%	1.000	51306	1.059
	93.77%	51253	96.89%	1.000	48176	0.940	95.38%	1.000	48465	0.946
gasnet_al1	3.04%	811877	3.04%	1.000	812138	1.000	3.04%	1.000	812144	1.000
	3.87%	1395011	3.87%	1.000	1392994	0.999	3.87%	1.000	1395305	1.000
	3.82%	880508	3.82%	1.000	879735	0.999	3.82%	1.000	880334	1.000
gasnet_al2	4.41%	971422	4.41%	1.000	972345	1.001	4.41%	1.000	970303	0.999
	4.60%	535084	4.60%	1.000	541653	1.012	4.60%	1.000	540631	1.010
	7.39%	1199521	7.39%	1.000	1198830	0.999	7.39%	1.000	1206451	1.006
gasnet_al3	1.65%	1286358	1.65%	1.000	1276704	0.992	1.65%	1.000	1285117	0.999
	2.52%	1583638	2.52%	1.000	1582424	0.999	2.52%	1.000	1579569	0.997
	5.11%	1017275	5.11%	1.000	1004906	0.988	5.11%	1.000	1013638	0.996
gasnet_al4	3.30%	1616745	2.54%	1.000	1525636	0.944	2.54%	1.000	1517481	0.939
	2.18%	1876547	2.18%	1.000	1873322	0.998	2.18%	1.000	1871020	0.997
	4.68%	1923757	4.68%	1.000	1904503	0.990	4.68%	1.000	1916313	0.996
gasprod_sarawak16	0.30%	1041083	0.31%	1.000	1159259	1.114	0.31%	1.000	1168902	1.123
	0.87%	1027510	0.21%	1.000	1137688	1.107	0.85%	1.000	1105765	1.076
	0.39%	940162	0.27%	1.000	1251407	1.331	0.36%	1.000	955681	1.017
gasprod_sarawak81	0.39%	212381	0.40%	1.000	193007	0.909	0.40%	1.000	192384	0.906
	0.39%	157406	0.39%	1.000	202851	1.289	0.39%	1.000	180943	1.149
	0.93%	173610	0.93%	1.000	153829	0.886	0.93%	1.000	151415	0.872

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
gastrans040	2.94	24	2.86	0.980	24	1.000	2.92	0.995	24	1.000
	∞	50	∞	1.000	50	1.000	∞	1.000	50	1.000
	0.93	1	0.93	1.000	1	1.000	0.94	1.005	1	1.000
gastrans135	∞	204	∞	1.000	300	1.316	∞	1.000	300	1.316
	∞	111	∞	1.000	111	1.000	∞	1.000	111	1.000
	∞	63	∞	1.000	63	1.000	∞	1.000	63	1.000
gastrans582_cold13	24.15	23	24.10	0.998	23	1.000	24.12	0.999	23	1.000
	∞	4662	∞	1.000	2289	0.502	∞	1.000	2289	0.502
gastrans582_cold13_95	∞	290	∞	1.000	288	0.995	∞	1.000	419	1.331
	20.97	711	21.04	1.003	711	1.000	21.03	1.003	711	1.000
	15.81	39	15.74	0.996	39	1.000	15.85	1.002	39	1.000
gastrans582_cold17	13.37	1	13.49	1.008	1	1.000	13.40	1.002	1	1.000
	20.25	54	20.20	0.998	54	1.000	20.28	1.001	54	1.000
	∞	3555	∞	1.000	6501	1.806	∞	1.000	4381	1.226
gastrans582_cold17_95	∞	2047	∞	1.000	1965	0.962	∞	1.000	817	0.427
	27.38	2	27.15	0.992	2	1.000	27.27	0.996	2	1.000
	39.43	73	39.22	0.995	73	1.000	39.43	1.000	73	1.000
gastrans582_cool12	∞	1275	∞	1.000	731	0.604	∞	1.000	795	0.651
	14.71	143	14.78	1.004	133	0.959	14.72	1.001	133	0.959
	60.61	63	57.69	0.953	61	0.988	58.18	0.961	61	0.988
gastrans582_cool12_95	∞	9512	∞	1.000	1077	0.122	∞	1.000	1337	0.150
	43.81	2	44.18	1.008	2	1.000	44.06	1.006	2	1.000
gastrans582_cool14	∞	1182	∞	1.000	136	0.184	∞	1.000	136	0.184
	∞	1805	∞	1.000	5121	2.741	∞	1.000	4843	2.595
	∞	9889	∞	1.000	149580	14.984	∞	1.000	115952	11.618
gastrans582_cool14_95	29.62	53	29.64	1.001	53	1.000	29.71	1.003	53	1.000
	∞	498	29.59	**0.004**	14	**0.191**	29.57	**0.004**	14	**0.191**
gastrans582_freezing27	6938.34	201210	5933.10	**0.855**	173626	**0.863**	172.52	**0.025**	5018	**0.025**
	154.80	1426	135.56	**0.877**	731	**0.545**	182.34	*1.177*	2149	*1.474*
	126.65	1680	127.33	1.005	1680	1.000	126.88	1.002	1680	1.000
gastrans582_freezing27_95	∞	313757	∞	1.000	313864	1.000	∞	1.000	170494	0.544
	∞	76620	6634.08	**0.921**	150414	*1.962*	∞	1.000	160332	2.091
	3485.18	35241	3462.83	0.994	35241	1.000	229.80	**0.066**	2725	**0.080**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
gastrans582_freezing30	∞	1127	∞	1.000	1564	1.356	∞	1.000	1564	1.356
gastrans582_mild10	∞	2665	∞	1.000	3741	1.389	1155.41	**0.161**	1901	**0.724**
	∞	2307	∞	1.000	2301	0.998	1653.53	**0.230**	1800	**0.789**
gastrans582_mild10_95	32.40	1	32.09	0.991	1	1.000	31.99	0.988	1	1.000
	16.60	57	16.67	1.004	57	1.000	16.59	0.999	57	1.000
gastrans582_mild11	∞	59976	∞	1.000	5612	0.095	∞	1.000	5208	0.088
	∞	42238	∞	1.000	849	0.022	5884.14	**0.817**	1683	**0.042**
	18.64	55	18.55	0.995	55	1.000	18.56	0.996	55	1.000
gastrans582_warm15	23.75	6	23.69	0.998	6	1.000	23.75	1.000	6	1.000
	14.09	13	14.22	1.009	13	1.000	14.14	1.003	13	1.000
	∞	76	∞	1.000	76	1.000	∞	1.000	76	1.000
gastrans582_warm15_95	∞	1755	∞	1.000	1767	1.006	∞	1.000	1955	1.108
	1610.39	12549	∞	4.469	3359	0.273	∞	4.469	3046	0.249
	∞	1119	∞	1.000	1230	1.091	∞	1.000	1207	1.072
gastrans582_warm31	35.46	18	35.56	1.003	18	1.000	35.57	1.003	18	1.000
	∞	338	∞	1.000	213	0.715	∞	1.000	213	0.715
	45.11	66	45.07	0.999	66	1.000	45.41	1.007	66	1.000
gastrans582_warm31_95	∞	12989	∞	1.000	46040	3.525	∞	1.000	50379	3.857
	40.66	101	40.76	1.002	101	1.000	40.90	1.006	101	1.000
	∞	765	∞	1.000	7546	8.839	∞	1.000	11235	13.104
gastrans	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
gbd	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
gear2	0.50	17	0.50	1.000	17	1.000	0.50	1.000	17	1.000
	0.50	17	0.50	1.000	17	1.000	0.50	1.000	17	1.000
	0.50	17	0.50	1.000	17	1.000	0.50	1.000	17	1.000
gear3	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
gear4	0.96	4579	0.99	1.015	4579	1.000	0.95	0.995	4579	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.90	4579	1.02	*1.063*	4579	1.000	1.00	*1.053*	4579	1.000
	0.96	4579	0.98	1.010	4579	1.000	0.99	1.015	4579	1.000
gear	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
genpooling_lee1	4.15	2292	4.10	0.990	2292	1.000	4.54	*1.076*	2042	**0.895**
	13.25	29271	13.41	1.011	29271	1.000	6.29	**0.512**	2950	**0.104**
	6.23	4639	6.22	0.999	4639	1.000	13.19	*1.963*	8122	*1.735*
genpooling_lee2	97.22	68646	97.27	1.001	68646	1.000	53.20	**0.552**	33994	**0.496**
	64.83	38240	65.30	1.007	38240	1.000	61.21	**0.945**	39835	1.042
	35.63	24343	37.23	1.044	23718	0.974	48.42	*1.349*	30869	*1.267*
genpooling_meyer04	102.25%	1207847	73.50%	1.000	1448789	1.199	86.04%	1.000	1242459	1.029
	84.25%	1283334	88.19%	1.000	1266565	0.987	85.56%	1.000	1276115	0.994
	121.88%	1233194	74.67%	1.000	1279278	1.037	82.99%	1.000	1339207	1.086
genpooling_meyer10	98.83%	1339149	96.82%	1.000	1240703	0.926	142.09%	1.000	1215388	0.908
	144.12%	1243942	96.69%	1.000	1282438	1.031	134.31%	1.000	1248459	1.004
	148.43%	1387695	111.59%	1.000	1383423	0.997	141.59%	1.000	1277119	0.920
genpooling_meyer15	84.03%	1127876	69.66%	1.000	1219518	1.081	89.20%	1.000	1118600	0.992
	97.39%	1031027	89.43%	1.000	1157177	1.122	84.59%	1.000	1147372	1.113
	90.41%	1100311	84.41%	1.000	1236617	1.124	80.91%	1.000	1128488	1.026
ghg_1veh	9.26	1402	9.14	0.988	1402	1.000	9.11	0.985	1402	1.000
	10.31	1732	10.29	0.998	1732	1.000	10.49	1.016	1732	1.000
gkocis	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
graphpart_2g-0044-1601	1.14	11	1.14	1.000	11	1.000	1.15	1.005	11	1.000
	0.62	23	0.64	1.012	23	1.000	0.65	1.019	23	1.000
	0.58	19	0.57	0.994	19	1.000	0.57	0.994	19	1.000
graphpart_2g-0055-0062	3.02	166	3.09	1.017	166	1.000	3.03	1.002	166	1.000
	3.33	159	3.24	0.979	159	1.000	3.34	1.002	159	1.000
	5.00	209	5.01	1.002	209	1.000	5.06	1.010	209	1.000
graphpart_2g-0066-0066	41.36	705	41.08	0.993	705	1.000	41.27	0.998	705	1.000
	58.86	1117	58.77	0.998	1117	1.000	58.89	1.001	1117	1.000
	56.04	991	56.01	0.999	991	1.000	56.06	1.000	991	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
graphpart_2g-0077-0077	562.78	6789	562.00	0.999	6789	1.000	561.05	0.997	6789	1.000
	776.72	8617	776.32	0.999	8617	1.000	776.48	1.000	8617	1.000
	668.60	8093	873.29	*1.306*	11396	*1.403*	875.81	*1.309*	11396	*1.403*
graphpart_2g-0088-0088	3.65%	29817	3.80%	1.000	28649	0.961	3.66%	1.000	29623	0.994
	3.85%	18260	3.86%	1.000	18197	0.997	3.86%	1.000	18164	0.995
	3.79%	26772	3.78%	1.000	26846	1.003	3.79%	1.000	26769	1.000
graphpart_2g-0099-9211	31.89%	10938	31.89%	1.000	10885	0.995	31.89%	1.000	10851	0.992
	29.48%	11767	27.84%	1.000	11956	1.016	27.84%	1.000	11917	1.013
	30.99%	10639	30.99%	1.000	10668	1.003	30.99%	1.000	10674	1.003
graphpart_2g-1010-0824	77.57%	590	77.57%	1.000	590	1.000	77.57%	1.000	590	1.000
	64.36%	490	64.37%	1.000	470	0.966	64.36%	1.000	493	1.005
	27.51%	1329	27.51%	1.000	1329	1.000	27.51%	1.000	1329	1.000
graphpart_2pm-0044-0044	0.50	224	0.50	1.000	118	**0.673**	0.50	1.000	118	**0.673**
	0.50	122	0.50	1.000	125	1.014	0.50	1.000	125	1.014
	0.50	123	0.50	1.000	123	1.000	0.50	1.000	123	1.000
graphpart_2pm-0055-0055	1.59	1305	1.74	*1.058*	1533	*1.162*	1.71	1.046	1533	*1.162*
	1.65	1210	1.90	*1.094*	1373	*1.124*	1.91	*1.098*	1373	*1.124*
	2.16	975	2.78	*1.196*	1052	*1.072*	2.77	*1.193*	1052	*1.072*
graphpart_2pm-0066-0066	2.29	884	2.20	0.973	954	*1.071*	2.25	0.988	954	*1.071*
	2.60	1005	2.08	**0.856**	750	**0.769**	2.15	**0.875**	750	**0.769**
	2.04	896	2.30	*1.086*	948	*1.052*	2.24	*1.066*	948	*1.052*
graphpart_2pm-0077-0777	10.20	1935	10.82	*1.055*	2334	*1.196*	10.80	*1.054*	2334	*1.196*
	6.14	1283	6.43	1.041	1392	*1.079*	6.41	1.038	1392	*1.079*
	11.01	3758	14.10	*1.257*	4342	*1.151*	14.01	*1.250*	4342	*1.151*
graphpart_2pm-0088-0888	6.39	2299	8.24	*1.250*	2725	*1.178*	8.25	*1.252*	2725	*1.178*
	13.03	4953	9.70	**0.763**	3729	**0.758**	9.59	**0.755**	3729	**0.758**
	9.73	2422	10.69	*1.089*	2423	1.000	10.81	*1.101*	2423	1.000
graphpart_2pm-0099-0999	52.13	6870	99.27	*1.887*	8404	*1.220*	99.56	*1.893*	8404	*1.220*
	79.90	10837	62.55	**0.786**	10890	1.005	62.16	**0.781**	10890	1.005
	46.03	5296	61.54	*1.330*	9166	*1.717*	61.51	*1.329*	9166	*1.717*
graphpart_3g-0234-0234	12.46	337	12.53	1.005	337	1.000	12.61	1.011	337	1.000
	13.35	235	13.33	0.999	235	1.000	13.27	0.994	235	1.000
	13.51	248	13.47	0.997	248	1.000	13.62	1.008	248	1.000
graphpart_3g-0244-0244	42.12	345	42.19	1.002	345	1.000	42.09	0.999	345	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	71.52	758	71.66	1.002	758	1.000	71.85	1.005	758	1.000
	42.42	431	42.52	1.002	431	1.000	42.80	1.009	431	1.000
graphpart_3g-0333-0333	19.00	521	26.25	*1.363*	712	*1.308*	26.32	*1.366*	712	*1.308*
	15.44	373	15.58	1.009	373	1.000	15.41	0.998	373	1.000
	38.50	809	38.53	1.001	809	1.000	38.48	0.999	809	1.000
graphpart_3g-0334-0334	455.57	5552	448.51	0.985	5585	1.006	450.65	0.989	5585	1.006
	598.02	7362	548.27	**0.917**	6502	**0.885**	548.73	**0.918**	6502	**0.885**
	527.85	6929	529.57	1.003	6929	1.000	528.62	1.001	6929	1.000
graphpart_3g-0344-0344	2576.81	13593	2577.99	1.000	13593	1.000	2599.35	1.009	13593	1.000
	2226.84	13447	2821.42	*1.267*	16222	*1.205*	2817.87	*1.265*	16222	*1.205*
	3278.45	17973	3246.82	0.990	17973	1.000	3261.57	0.995	17973	1.000
graphpart_3g-0444-0444	20.02%	7632	20.00%	1.000	7651	1.002	20.00%	1.000	7651	1.002
	18.68%	7038	18.76%	1.000	7004	0.995	18.76%	1.000	6997	0.994
	19.01%	6561	19.01%	1.000	6561	1.000	19.01%	1.000	6561	1.000
graphpart_3pm-0234-0234	4.90	1381	5.66	*1.129*	1907	*1.355*	5.56	*1.112*	1907	*1.355*
	1.56	856	1.60	1.016	862	1.006	1.60	1.016	862	1.006
	1.39	886	1.58	*1.079*	873	0.987	1.58	*1.079*	873	0.987
graphpart_3pm-0244-0244	23.41	5072	24.32	1.037	5118	1.009	24.35	1.039	5118	1.009
	21.43	5623	21.13	0.987	4282	**0.766**	21.32	0.995	4282	**0.766**
	16.57	4163	16.92	1.020	3644	**0.878**	16.92	1.020	3644	**0.878**
graphpart_3pm-0333-0333	11.99	2647	11.62	0.972	2922	*1.100*	11.66	0.975	2922	*1.100*
	6.64	1632	5.64	**0.869**	1459	**0.900**	5.74	**0.882**	1459	**0.900**
	7.49	2406	8.70	*1.143*	2610	*1.081*	8.57	*1.127*	2610	*1.081*
graphpart_3pm-0334-0334	57.75	12719	66.34	*1.146*	15360	*1.206*	66.56	*1.150*	15360	*1.206*
	47.17	14351	49.73	*1.053*	17934	*1.248*	49.63	*1.051*	17934	*1.248*
	58.75	23508	67.36	*1.144*	25352	*1.078*	67.80	*1.151*	25352	*1.078*
graphpart_3pm-0344-0344	666.67	317554	636.31	0.955	360039	*1.134*	640.09	0.960	360039	*1.134*
	436.24	215740	606.40	*1.389*	295908	*1.371*	609.07	*1.395*	295908	*1.371*
	985.75	334535	1084.89	*1.100*	404051	*1.208*	1082.18	*1.098*	404051	*1.208*
graphpart_3pm-0444-0444	14.71%	3523996	17.65%	1.000	3549896	1.007	17.66%	1.000	3541699	1.005
	19.82%	3002615	17.80%	1.000	2875151	0.958	17.82%	1.000	2863834	0.954
	20.18%	2508832	20.24%	1.000	2689197	1.072	20.23%	1.000	2695554	1.074
graphpart_clique-20	12.77	2743	11.65	**0.919**	3085	*1.120*	11.55	**0.911**	3085	*1.120*
	14.25	3371	13.05	**0.921**	3126	**0.929**	13.08	**0.923**	3126	**0.929**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	11.77	2667	14.19	*1.190*	3068	*1.145*	14.20	*1.190*	3068	*1.145*
graphpart_clique-30	173.26	40952	116.60	**0.675**	24833	**0.607**	116.18	**0.672**	24833	**0.607**
	98.78	15190	97.92	0.991	14221	**0.937**	98.67	0.999	14221	**0.937**
	180.55	19713	162.23	**0.899**	18544	**0.941**	162.43	**0.900**	18544	**0.941**
graphpart_clique-40	861.40	506741	660.55	**0.767**	401476	**0.792**	660.50	**0.767**	401476	**0.792**
	962.71	624930	1532.65	*1.591*	819272	*1.311*	1528.90	*1.588*	819272	*1.311*
	772.68	368811	723.20	**0.936**	321347	**0.871**	723.07	**0.936**	321347	**0.871**
graphpart_clique-50	168.77%	3657206	131.12%	1.000	4421349	1.209	130.82%	1.000	4453476	1.218
	5629.60	2611816	6619.20	*1.176*	2561406	0.981	6623.48	*1.177*	2561406	0.981
	5990.57	2554840	5697.56	0.951	2464068	0.964	5715.30	0.954	2464068	0.964
graphpart_clique-60	412.12%	985368	399.73%	1.000	863317	0.876	414.63%	1.000	825968	0.838
	386.84%	843859	472.13%	1.000	1162398	1.377	472.24%	1.000	1145008	1.357
	374.84%	782240	355.40%	1.000	720172	0.921	372.41%	1.000	733548	0.938
graphpart_clique-70	3574.38%	598380	2744.45%	1.000	448699	0.750	1678.22%	1.000	317711	0.531
	1739.22%	669819	2341.95%	1.000	562137	0.839	2416.10%	1.000	611840	0.913
	624.45%	493360	1267.18%	1.000	521735	1.058	1235.29%	1.000	515117	1.044
hadamard_4	0.50	139	0.50	1.000	139	1.000	0.50	1.000	139	1.000
	0.50	139	0.50	1.000	139	1.000	0.50	1.000	139	1.000
	0.50	139	0.50	1.000	139	1.000	0.50	1.000	139	1.000
hadamard_5	56.87	84303	60.29	*1.059*	80984	0.961	60.55	*1.064*	80984	0.961
	57.14	84303	60.31	*1.055*	80984	0.961	60.16	*1.052*	80984	0.961
	56.92	84303	60.61	*1.064*	80984	0.961	59.70	1.048	80984	0.961
hadamard_6	977.78%	2574288	986.11%	1.000	2418339	0.939	985.19%	1.000	2425477	0.942
	974.07%	2608338	986.11%	1.000	2420785	0.928	986.11%	1.000	2422801	0.929
	977.78%	2578978	985.19%	1.000	2431194	0.943	985.19%	1.000	2436487	0.945
hadamard_7	$\geq$ 10000%	5891	$\geq$ 10000%	1.000	6842	1.159	$\geq$ 10000%	1.000	6842	1.159
	$\geq$ 10000%	5804	$\geq$ 10000%	1.000	6841	1.176	$\geq$ 10000%	1.000	6841	1.176
	$\geq$ 10000%	5804	$\geq$ 10000%	1.000	6841	1.176	$\geq$ 10000%	1.000	6841	1.176
hadamard_8	∞	8	∞	1.000	8	1.000	∞	1.000	8	1.000
	∞	8	∞	1.000	8	1.000	∞	1.000	8	1.000
	∞	8	∞	1.000	8	1.000	∞	1.000	8	1.000
hadamard_9	∞	0	∞	1.000	0	1.000	∞	1.000	0	1.000
	∞	0	∞	1.000	0	1.000	∞	1.000	0	1.000
	∞	0	∞	1.000	0	1.000	∞	1.000	0	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
hda	1097.33%	34929	∞	1.000	258966	7.396	∞	1.000	37543	1.075
	332.34%	437952	392.66%	1.000	394423	0.901	383.72%	1.000	409456	0.935
	∞	51	∞	1.000	51	1.000	∞	1.000	51	1.000
heatexch_gen2	∞	9256	∞	1.000	9256	1.000	∞	1.000	13009	1.401
	∞	8839	∞	1.000	8839	1.000	∞	1.000	8839	1.000
heatexch_gen3	∞	1094	∞	1.000	1094	1.000	∞	1.000	1094	1.000
	∞	3090	∞	1.000	3025	0.980	∞	1.000	3025	0.980
	∞	14498	∞	1.000	3051	0.216	∞	1.000	3051	0.216
heatexch_spec1	1.12%	4558327	1.12%	1.000	5088443	1.116	1.18%	1.000	16976768	3.724
	1.38%	5815842	0.98%	1.000	3797154	0.653	7.61%	1.000	2355764	0.405
	0.69%	6669693	0.70%	1.000	7573331	1.135	0.70%	1.000	7884183	1.182
heatexch_spec2	6.02%	3569492	6.90%	1.000	1505435	0.422	4.86%	1.000	1930575	0.541
	6.56%	4077931	46.67%	1.000	1681226	0.412	9.72%	1.000	3992195	0.979
	4.78%	2259499	44.98%	1.000	7003	0.003	44.98%	1.000	7003	0.003
heatexch_spec3	60.34%	2891526	55.43%	1.000	2075563	0.718	78.56%	1.000	2625843	0.908
	77.98%	2291921	54.29%	1.000	2109767	0.921	55.31%	1.000	1745434	0.762
hmittelman	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
hvb11	24.17	5640	24.27	1.004	5749	1.019	24.47	1.012	5749	1.019
	12.66	1644	13.13	1.034	1859	*1.123*	12.93	1.020	1859	*1.123*
	12.17	1117	11.89	0.979	917	**0.836**	11.97	0.985	917	**0.836**
hybriddynamic_fixed	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
hybriddynamic_var	1.86	2021	1.39	**0.836**	821	**0.434**	1.43	**0.850**	821	**0.434**
	1.72	1961	1.44	**0.897**	761	**0.418**	1.40	**0.882**	761	**0.418**
	1.73	1781	1.49	**0.912**	1046	**0.609**	1.40	**0.879**	1046	**0.609**
hydroenergy1	3114.14	3348551	3158.11	1.014	3342201	0.998	3178.62	1.021	3342201	0.998
	0.01%	7915235	0.01%	1.000	7796952	0.985	0.01%	1.000	7702145	0.973
	4368.26	4613451	4395.87	1.006	4613451	1.000	4432.33	1.015	4613451	1.000
hydroenergy2	0.75%	2097781	0.75%	1.000	2089060	0.996	0.75%	1.000	2098014	1.000
	0.67%	1873677	0.67%	1.000	1868048	0.997	0.67%	1.000	1862374	0.994
	1.01%	1934855	1.01%	1.000	1928201	0.997	1.01%	1.000	1930422	0.998

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
hydroenergy3	1.91%	616940	1.91%	1.000	618340	1.002	1.91%	1.000	618445	1.002
	1.89%	610174	1.89%	1.000	609640	0.999	1.89%	1.000	610934	1.001
	1.82%	642464	1.82%	1.000	641092	0.998	1.82%	1.000	641896	0.999
ising2_5-300_5555	9863.59%	76	9864.36%	1.000	69	0.960	9864.36%	1.000	69	0.960
	9863.59%	76	9864.36%	1.000	69	0.960	9864.36%	1.000	69	0.960
	9863.59%	76	9864.36%	1.000	69	0.960	9864.36%	1.000	69	0.960
jit1	0.50	158	0.50	1.000	158	1.000	0.50	1.000	158	1.000
	0.50	158	0.50	1.000	158	1.000	0.50	1.000	158	1.000
	0.50	158	0.50	1.000	158	1.000	0.50	1.000	158	1.000
kport20	661.02	606741	495.64	**0.750**	571892	**0.943**	315.82	**0.479**	190105	**0.313**
	722.40	704971	388.71	**0.539**	339688	**0.482**	903.65	*1.251*	682721	0.968
	5.58%	1688868	1902.94	**0.264**	761986	**0.451**	887.61	**0.123**	536344	**0.318**
kport40	26.38%	352155	23.01%	1.000	330083	0.937	25.80%	1.000	343012	0.974
	26.44%	282983	25.79%	1.000	285532	1.009	26.66%	1.000	276195	0.976
	23.91%	413370	23.94%	1.000	355601	0.860	23.80%	1.000	343620	0.831
lip	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
lop97ic	75.65%	101986	75.65%	1.000	105327	1.033	75.87%	1.000	107880	1.058
	73.71%	98706	75.12%	1.000	100489	1.018	75.12%	1.000	103393	1.047
	79.52%	93428	82.97%	1.000	96329	1.031	80.42%	1.000	95749	1.025
lop97icx	50.91%	89722	50.25%	1.000	92707	1.033	49.38%	1.000	91605	1.021
	49.84%	83686	52.20%	1.000	86133	1.029	51.37%	1.000	88033	1.052
	47.47%	111141	50.34%	1.000	88452	0.796	52.83%	1.000	92633	0.834
m3	0.90	7	0.89	0.995	7	1.000	0.88	0.989	7	1.000
	0.57	15	0.58	1.006	15	1.000	0.57	1.000	15	1.000
	1.13	9	1.14	1.005	9	1.000	1.12	0.995	9	1.000
m6	1.51	244	1.62	1.044	259	1.044	1.58	1.028	259	1.044
	1.59	168	1.80	*1.081*	130	**0.858**	1.82	*1.089*	130	**0.858**
	3.17	956	2.22	**0.772**	724	**0.780**	2.20	**0.767**	724	**0.780**
m7	3.61	499	3.62	1.002	329	**0.716**	3.67	1.013	329	**0.716**
	5.19	1102	4.57	**0.900**	864	**0.802**	4.60	**0.905**	864	**0.802**
	4.68	1430	4.53	0.974	1381	0.968	4.52	0.972	1381	0.968
m7_ar25_1	1.31	759	1.37	1.026	536	**0.740**	1.36	1.022	536	**0.740**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1.78	733	1.59	**0.932**	613	**0.856**	1.65	0.953	613	**0.856**
	1.38	669	0.72	**0.723**	543	**0.836**	0.70	**0.714**	543	**0.836**
m7_ar2_1	4.53	5695	5.41	*1.159*	5507	0.968	5.35	*1.148*	5507	0.968
	6.96	6701	5.04	**0.759**	5757	**0.861**	5.03	**0.758**	5757	**0.861**
	5.22	5949	5.68	*1.074*	5910	0.994	5.63	*1.066*	5910	0.994
m7_ar3_1	7.37	5746	8.19	*1.098*	5837	1.016	8.24	*1.104*	5885	1.024
	7.13	6245	5.66	**0.819**	4306	**0.694**	5.56	**0.807**	4306	**0.694**
	7.65	7043	9.32	*1.193*	7487	*1.062*	9.52	*1.216*	7487	*1.062*
m7_ar4_1	2.94	1028	2.24	**0.822**	978	0.956	2.28	**0.832**	978	0.956
	2.78	656	1.92	**0.772**	581	**0.901**	1.93	**0.775**	581	**0.901**
	2.09	394	2.17	1.026	636	*1.490*	2.19	1.032	636	*1.490*
m7_ar5_1	5.95	4140	7.31	*1.196*	4090	0.988	7.34	*1.200*	4090	0.988
	3.99	2760	6.74	*1.551*	3671	*1.319*	6.67	*1.537*	3671	*1.319*
	3.78	1837	3.05	**0.847**	1682	**0.920**	3.05	**0.847**	1682	**0.920**
maxcsp-ehi-85-297-12	∞	655142	∞	1.000	622828	0.951	∞	1.000	625859	0.955
	∞	687216	∞	1.000	500609	0.728	∞	1.000	501940	0.730
	∞	901666	∞	1.000	829639	0.920	∞	1.000	830405	0.921
maxcsp-ehi-85-297-36	∞	752895	∞	1.000	730802	0.971	∞	1.000	729825	0.969
	∞	588313	∞	1.000	590979	1.005	∞	1.000	590074	1.003
	∞	801010	∞	1.000	869577	1.086	∞	1.000	871458	1.088
maxcsp-ehi-85-297-71	∞	634607	∞	1.000	543020	0.856	∞	1.000	538161	0.848
	∞	721949	∞	1.000	788776	1.093	∞	1.000	786826	1.090
	∞	667593	∞	1.000	613972	0.920	∞	1.000	613063	0.918
maxcsp-ehi-90-315-70	∞	770987	∞	1.000	780342	1.012	∞	1.000	785021	1.018
	∞	879799	∞	1.000	733830	0.834	∞	1.000	731493	0.831
	∞	604475	∞	1.000	566971	0.938	∞	1.000	566915	0.938
maxcsp-geo50-20-d4-75-36	800.59	199203	1080.99	*1.350*	279086	*1.401*	1076.61	*1.344*	279086	*1.401*
	604.20	145140	351.25	**0.582**	86199	**0.594**	352.58	**0.584**	86199	**0.594**
	371.47	99502	488.64	*1.315*	120814	*1.214*	490.25	*1.319*	120814	*1.214*
maxcsp-langford-3-11	∞	4388833	∞	1.000	3750352	0.855	∞	1.000	3643191	0.830
	∞	4068541	∞	1.000	3812836	0.937	∞	1.000	3836290	0.943
	∞	4172074	∞	1.000	4085243	0.979	∞	1.000	4163341	0.998
mbtd	236.67%	463	190.00%	1.000	764	1.535	190.00%	1.000	764	1.535
	173.33%	1357	180.00%	1.000	1193	0.887	180.00%	1.000	1189	0.885

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	233.34%	715	183.33%	1.000	500	0.736	183.33%	1.000	500	0.736
meanvar-orl400_05_e_8	130.95	78273	130.90	1.000	75593	0.966	131.19	1.002	75593	0.966
	143.63	91674	75.42	**0.528**	2708	**0.031**	75.10	**0.526**	2708	**0.031**
	120.17	77632	120.33	1.001	75362	0.971	120.53	1.003	75362	0.971
meanvarx	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
milinfract	56.13	9	55.98	0.997	9	1.000	55.69	0.992	9	1.000
	92.45	2	91.95	0.995	2	1.000	92.56	1.001	2	1.000
	51.33	2	51.64	1.006	2	1.000	51.52	1.004	2	1.000
minlphix	∞	45177	∞	1.000	45177	1.000	∞	1.000	45177	1.000
	∞	94160	∞	1.000	94160	1.000	∞	1.000	94160	1.000
multiplants_mtg1b	168.34%	355737	147.83%	1.000	334594	0.941	134.15%	1.000	332887	0.936
	168.20%	360834	120.78%	1.000	364797	1.011	162.52%	1.000	338980	0.939
	156.41%	391997	152.08%	1.000	330729	0.844	188.26%	1.000	330441	0.843
multiplants_mtg1c	563.92%	338095	524.02%	1.000	300346	0.888	517.24%	1.000	314281	0.930
	506.79%	341383	504.17%	1.000	303445	0.889	495.38%	1.000	308231	0.903
multiplants_mtg5	25.45%	919872	6.36%	1.000	914752	0.994	3.37%	1.000	798006	0.868
	18.65%	1194683	8.19%	1.000	1216753	1.018	4.84%	1.000	1182300	0.990
	12.59%	953152	19.54%	1.000	1011344	1.061	17.77%	1.000	1089816	1.143
multiplants_mtg6	15.79%	706962	13.61%	1.000	462163	0.654	15.06%	1.000	522724	0.739
	15.31%	625728	14.38%	1.000	467375	0.747	13.69%	1.000	421928	0.674
	15.04%	641369	14.40%	1.000	415514	0.648	17.30%	1.000	476840	0.744
multiplants_stg1	∞	309	∞	1.000	309	1.000	∞	1.000	308	0.998
	∞	609	∞	1.000	609	1.000	∞	1.000	611	1.003
	∞	34	∞	1.000	34	1.000	∞	1.000	34	1.000
multiplants_stg1a	∞	1154	∞	1.000	1206	1.041	∞	1.000	334	0.346
	∞	7837	∞	1.000	1523	0.204	∞	1.000	1704	0.227
	∞	1260	∞	1.000	262	0.266	∞	1.000	499	0.440
multiplants_stg1b	∞	2054	∞	1.000	2063	1.004	∞	1.000	2059	1.002
	∞	561	∞	1.000	561	1.000	∞	1.000	553	0.988
	∞	4617	∞	1.000	4630	1.003	∞	1.000	2453	0.541
multiplants_stg1c	∞	1329	∞	1.000	233	0.233	∞	1.000	3396	2.446
	∞	2083	∞	1.000	2389	1.140	∞	1.000	1928	0.929

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	3000	∞	1.000	1908	0.648	∞	1.000	609	0.229
multiplants_stg5	∞	479	∞	1.000	479	1.000	∞	1.000	1389	2.572
	∞	2808	∞	1.000	2758	0.983	∞	1.000	710	0.279
	∞	1315	∞	1.000	237	0.238	∞	1.000	327	0.302
multiplants_stg6	∞	143	∞	1.000	143	1.000	∞	1.000	143	1.000
	∞	343	∞	1.000	345	1.005	∞	1.000	343	1.000
ndcc12	∞	315450	∞	1.000	216516	0.686	∞	1.000	295502	0.937
	∞	221586	∞	1.000	271025	1.223	∞	1.000	189884	0.857
	∞	279688	∞	1.000	150055	0.537	∞	1.000	338744	1.211
ndcc12persp	∞	2231301	∞	1.000	1104230	0.495	∞	1.000	1799510	0.806
	∞	1318647	∞	1.000	1166865	0.885	∞	1.000	1503834	1.140
	∞	1407899	∞	1.000	1169783	0.831	∞	1.000	636717	0.452
ndcc13	25.15%	519639	25.15%	1.000	323364	0.622	23.08%	1.000	608104	1.170
	25.62%	415375	27.65%	1.000	410142	0.987	27.39%	1.000	357263	0.860
	24.83%	384762	23.08%	1.000	1224070	3.181	24.24%	1.000	241377	0.627
ndcc13persp	31.19%	613391	28.76%	1.000	806522	1.315	22.82%	1.000	729567	1.189
	19.18%	698637	19.56%	1.000	885473	1.267	20.93%	1.000	518850	0.743
	25.27%	380482	22.80%	1.000	597549	1.570	24.17%	1.000	503913	1.324
ndcc14	90.90%	11149	89.85%	1.000	30443	2.715	84.09%	1.000	13037	1.168
	93.94%	8896	90.63%	1.000	37588	4.189	91.28%	1.000	42604	4.747
	82.75%	93550	92.34%	1.000	17243	0.185	102.72%	1.000	12324	0.133
ndcc14persp	89.17%	1089278	90.73%	1.000	846506	0.777	88.36%	1.000	859906	0.789
	80.36%	927503	80.83%	1.000	729191	0.786	81.15%	1.000	995506	1.073
	94.07%	1515724	93.54%	1.000	743083	0.490	93.19%	1.000	942744	0.622
ndcc15	26.42%	24853	25.58%	1.000	22400	0.902	25.40%	1.000	23662	0.952
	26.90%	32485	25.03%	1.000	41949	1.290	25.30%	1.000	37789	1.163
	30.21%	10824	25.00%	1.000	27204	2.499	24.84%	1.000	31707	2.912
ndcc15persp	29.69%	747922	26.88%	1.000	724582	0.969	32.55%	1.000	1198909	1.603
	28.99%	873424	25.95%	1.000	490760	0.562	24.41%	1.000	799040	0.915
	∞	342692	∞	1.000	1081146	3.154	∞	1.000	893908	2.608
ndcc16	100.04%	32557	100.42%	1.000	30016	0.922	100.77%	1.000	24667	0.758
	∞	79647	∞	1.000	79827	1.002	∞	1.000	57472	0.722
	100.08%	86303	99.42%	1.000	57826	0.670	99.19%	1.000	102344	1.186
ndcc16persp	∞	780591	∞	1.000	553549	0.709	∞	1.000	427182	0.547

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	635644	∞	1.000	591876	0.931	∞	1.000	695193	1.094
	∞	665085	∞	1.000	273005	0.411	∞	1.000	573514	0.862
netmod_dol1	1416.41	54697	1376.50	0.972	56761	1.038	1372.60	0.969	56761	1.038
	1489.41	56665	1625.62	*1.091*	56260	0.993	1631.30	*1.095*	56260	0.993
	2169.71	53806	2147.23	0.990	52948	0.984	2153.39	0.992	52948	0.984
netmod_dol2	38.68	224	33.77	**0.876**	158	**0.796**	33.67	**0.874**	158	**0.796**
	38.99	218	38.89	0.997	214	0.987	38.82	0.996	214	0.987
	38.73	143	39.16	1.011	141	0.992	39.12	1.010	141	0.992
netmod_kar1	7.82	470	6.90	**0.896**	455	0.974	6.91	**0.897**	455	0.974
	8.52	397	9.95	*1.150*	498	*1.203*	9.87	*1.142*	498	*1.203*
	10.78	441	8.76	**0.829**	386	**0.898**	8.77	**0.829**	386	**0.898**
netmod_kar2	7.84	470	6.87	**0.890**	455	0.974	6.95	**0.899**	455	0.974
	8.49	397	9.93	*1.152*	498	*1.203*	9.88	*1.146*	498	*1.203*
	10.71	441	8.83	**0.839**	386	**0.898**	8.81	**0.838**	386	**0.898**
no7_ar25_1	34.63	43187	35.26	1.018	44506	1.030	33.63	0.972	44600	1.033
	42.10	58532	38.87	**0.925**	54454	**0.930**	39.20	**0.933**	54454	**0.930**
	44.23	48245	41.95	**0.950**	49287	1.022	43.11	0.975	49874	1.034
no7_ar2_1	23.36	26120	18.71	**0.809**	19042	**0.730**	18.67	**0.807**	19042	**0.730**
	20.97	23800	21.06	1.004	24414	1.026	21.06	1.004	24414	1.026
	19.14	21929	17.28	**0.908**	18392	**0.839**	17.28	**0.908**	18392	**0.839**
no7_ar3_1	206.35	393305	100.39	**0.489**	165927	**0.422**	101.36	**0.494**	167525	**0.426**
	133.08	224981	107.62	**0.810**	186254	**0.828**	107.27	**0.808**	186254	**0.828**
	110.97	194374	88.86	**0.803**	156488	**0.805**	86.87	**0.785**	156551	**0.806**
no7_ar4_1	92.95	144407	96.83	1.041	146953	1.018	93.50	1.006	145381	1.007
	128.72	194208	116.14	**0.903**	171945	**0.885**	116.48	**0.906**	174472	**0.898**
	121.89	170770	162.00	*1.326*	237108	*1.388*	159.49	*1.306*	234034	*1.370*
no7_ar5_1	64.06	80824	60.80	**0.950**	83092	1.028	64.43	1.006	85793	*1.061*
	71.86	97731	66.80	**0.931**	84633	**0.866**	67.94	**0.946**	84668	**0.866**
	65.09	82027	83.70	*1.282*	109634	*1.336*	88.18	*1.349*	110891	*1.351*
nous1	4.84%	4607584	4.89%	1.000	4581265	0.994	8.60%	1.000	4499945	0.977
	6243.27	3890131	6288.08	1.007	3890131	1.000	0.01%	1.153	5535147	1.423
nous2	7.79	7003	7.62	0.981	7003	1.000	7.65	0.984	7003	1.000
	8.64	5591	8.58	0.994	5591	1.000	8.68	1.004	5591	1.000
	5.66	2643	5.70	1.006	2643	1.000	5.68	1.003	2643	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
nuclear10a	∞	93	∞	1.000	94	1.005	∞	1.000	93	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
nuclear10b	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
nuclear14	∞	5685	∞	1.000	5685	1.000	∞	1.000	5685	1.000
	∞	41571	∞	1.000	41571	1.000	∞	1.000	41571	1.000
	∞	6540	∞	1.000	6540	1.000	∞	1.000	6540	1.000
nuclear14a	≥ 10000%	14103	≥ 10000%	1.000	14197	1.007	≥ 10000%	1.000	11414	0.811
	≥ 10000%	8459	≥ 10000%	1.000	8469	1.001	≥ 10000%	1.000	9370	1.106
	≥ 10000%	11028	≥ 10000%	1.000	11065	1.003	≥ 10000%	1.000	11883	1.077
nuclear14b	87.87%	6969	87.87%	1.000	5913	0.851	87.87%	1.000	1100	0.170
	93.91%	3881	94.11%	1.000	4522	1.161	94.11%	1.000	4588	1.178
	83.97%	5943	83.97%	1.000	5750	0.968	83.24%	1.000	2825	0.484
nuclear25	∞	6119	∞	1.000	6119	1.000	∞	1.000	6119	1.000
	∞	655	∞	1.000	655	1.000	∞	1.000	655	1.000
	∞	23643	∞	1.000	23643	1.000	∞	1.000	23643	1.000
nuclear25a	≥ 10000%	14711	≥ 10000%	1.000	14683	0.998	∞	1.000	9716	0.663
	≥ 10000%	4127	≥ 10000%	1.000	4127	1.000	≥ 10000%	1.000	7989	1.914
	∞	5402	∞	1.000	4768	0.885	≥ 10000%	1.000	17142	3.134
nuclear25b	109.05%	6472	114.81%	1.000	6871	1.061	114.06%	1.000	7228	1.115
	106.42%	11009	106.96%	1.000	8638	0.787	106.96%	1.000	8246	0.751
	1045.49%	5158	1029.01%	1.000	6973	1.345	∞	1.000	1	0.019
nuclear49	∞	17066	∞	1.000	17066	1.000	∞	1.000	17066	1.000
	∞	108412	∞	1.000	108412	1.000	∞	1.000	108412	1.000
	∞	103070	∞	1.000	103070	1.000	∞	1.000	103070	1.000
nuclear49a	∞	4285	∞	1.000	4832	1.125	∞	1.000	4507	1.051
	∞	3956	∞	1.000	3983	1.007	∞	1.000	3236	0.822
	∞	3185	∞	1.000	3215	1.009	∞	1.000	5099	1.583
nuclear49b	1084.48%	1	1084.48%	1.000	1	1.000	1084.48%	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	1061.39%	1	1061.39%	1.000	1	1.000	1061.39%	1.000	1	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
nuclearva	∞	18816	∞	1.000	18816	1.000	∞	1.000	18816	1.000
	∞	6046	∞	1.000	6046	1.000	∞	1.000	6046	1.000
	∞	8666	∞	1.000	8666	1.000	∞	1.000	8666	1.000
nuclearvb	∞	24660	∞	1.000	24660	1.000	∞	1.000	24660	1.000
	∞	2344	∞	1.000	2344	1.000	∞	1.000	2344	1.000
	∞	9956	∞	1.000	9956	1.000	∞	1.000	9956	1.000
nuclearvc	∞	2091	∞	1.000	2091	1.000	∞	1.000	2091	1.000
	∞	943	∞	1.000	943	1.000	∞	1.000	943	1.000
	∞	827	∞	1.000	827	1.000	∞	1.000	827	1.000
nuclearvd	∞	585841	∞	1.000	599839	1.024	∞	1.000	599839	1.024
	∞	420947	∞	1.000	1998356	4.746	∞	1.000	1998356	4.746
	∞	1866538	∞	1.000	119578	0.064	∞	1.000	119578	0.064
nuclearve	∞	896895	∞	1.000	493120	0.550	∞	1.000	493120	0.550
	∞	1568678	∞	1.000	289073	0.184	∞	1.000	289073	0.184
	∞	772677	∞	1.000	354383	0.459	∞	1.000	354383	0.459
nuclearvf	∞	552062	∞	1.000	1940789	3.515	∞	1.000	1940789	3.515
	∞	1237622	∞	1.000	979444	0.791	∞	1.000	979444	0.791
	∞	715200	∞	1.000	1811832	2.533	∞	1.000	1811832	2.533
nvs01	0.50	19	0.50	1.000	19	1.000	0.50	1.000	19	1.000
	0.50	19	0.50	1.000	19	1.000	0.50	1.000	19	1.000
	0.50	19	0.50	1.000	19	1.000	0.50	1.000	19	1.000
nvs02	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs03	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs04	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs05	4.56	646	4.52	0.993	646	1.000	4.49	0.987	646	1.000
	0.63	133	0.58	0.969	133	1.000	0.60	0.982	133	1.000
	6.30	959	6.27	0.996	959	1.000	6.35	1.007	959	1.000
nvs06	0.50	12	0.50	1.000	12	1.000	0.50	1.000	12	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	12	0.50	1.000	12	1.000	0.50	1.000	12	1.000
	0.50	12	0.50	1.000	12	1.000	0.50	1.000	12	1.000
nvs07	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs08	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
nvs09	2230.28	2753790	2246.33	1.007	2753790	1.000	2240.08	1.004	2737298	0.994
	2234.45	2753790	2258.29	1.011	2753790	1.000	2243.84	1.004	2737298	0.994
	2233.43	2753790	2240.83	1.003	2753790	1.000	2253.55	1.009	2737298	0.994
nvs10	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs11	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs12	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
nvs13	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
nvs14	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs15	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs16	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
nvs17	0.50	44	0.50	1.000	43	0.993	0.50	1.000	43	0.993
	0.50	44	0.50	1.000	43	0.993	0.50	1.000	43	0.993

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	44	0.50	1.000	43	0.993	0.50	1.000	43	0.993
nvs18	0.50	27	0.50	1.000	27	1.000	0.50	1.000	27	1.000
	0.50	39	0.50	1.000	35	0.971	0.50	1.000	35	0.971
	0.50	40	0.50	1.000	26	**0.900**	0.50	1.000	26	**0.900**
nvs19	0.50	103	0.50	1.000	97	0.970	0.50	1.000	97	0.970
	0.50	109	0.50	1.000	101	0.962	0.50	1.000	101	0.962
	0.50	116	0.50	1.000	100	**0.926**	0.50	1.000	100	**0.926**
nvs20	1.79	112	1.77	0.993	112	1.000	1.80	1.004	112	1.000
	1.74	118	1.80	1.022	118	1.000	1.75	1.004	118	1.000
nvs21	0.50	30	0.50	1.000	30	1.000	0.50	1.000	30	1.000
	0.50	30	0.50	1.000	30	1.000	0.50	1.000	30	1.000
	0.50	30	0.50	1.000	30	1.000	0.50	1.000	30	1.000
nvs23	0.50	175	0.50	1.000	156	**0.931**	0.50	1.000	156	**0.931**
	0.59	147	0.60	1.006	123	**0.903**	0.63	1.025	123	**0.903**
	0.50	163	0.50	1.000	137	**0.901**	0.50	1.000	137	**0.901**
nvs24	0.58	147	0.59	1.006	157	1.040	0.56	0.987	157	1.040
	0.58	206	0.62	1.025	165	**0.866**	0.61	1.019	165	**0.866**
	0.77	191	0.69	0.955	203	1.041	0.68	**0.949**	203	1.041
o7	3650.26	6501371	2987.98	**0.819**	5342403	**0.822**	2938.58	**0.805**	5251288	**0.808**
	3696.48	6280532	1591.38	**0.431**	2696843	**0.429**	1711.27	**0.463**	2959949	**0.471**
	3151.71	5387430	2285.18	**0.725**	4112905	**0.763**	2311.07	**0.733**	4093496	**0.760**
o7_2	957.98	1746312	1173.84	*1.225*	2085189	*1.194*	1174.27	*1.226*	2109038	*1.208*
	1233.69	1995456	920.72	**0.747**	1543138	**0.773**	925.54	**0.750**	1543192	**0.773**
	723.80	1269425	898.80	*1.241*	1517303	*1.195*	913.00	*1.261*	1523837	*1.200*
o7_ar25_1	374.05	637130	242.46	**0.649**	408245	**0.641**	237.57	**0.636**	406967	**0.639**
	357.69	598723	252.07	**0.706**	417170	**0.697**	256.84	**0.719**	424927	**0.710**
	397.95	698287	344.45	**0.866**	581506	**0.833**	352.10	**0.885**	580335	**0.831**
o7_ar2_1	117.59	205854	77.38	**0.661**	127615	**0.620**	77.08	**0.658**	127615	**0.620**
	128.28	226546	77.30	**0.606**	128820	**0.569**	81.02	**0.634**	130010	**0.574**
	152.24	253540	79.39	**0.525**	130518	**0.515**	78.89	**0.521**	130456	**0.515**
o7_ar3_1	935.58	1625660	479.58	**0.513**	855875	**0.527**	506.45	**0.542**	881595	**0.542**
	1166.72	2019484	588.11	**0.504**	1033184	**0.512**	578.28	**0.496**	1012031	**0.501**
	591.98	1069256	460.27	**0.778**	823092	**0.770**	399.40	**0.675**	719287	**0.673**
o7_ar4_1	2155.45	3481580	619.99	**0.288**	1072014	**0.308**	621.62	**0.289**	1070472	**0.307**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1844.66	3135326	949.68	**0.515**	1658019	**0.529**	898.22	**0.487**	1531943	**0.489**
	1659.34	2782874	1163.62	**0.701**	1991198	**0.716**	1093.27	**0.659**	1872803	**0.673**
o7_ar5_1	423.08	700674	369.74	**0.874**	598325	**0.854**	372.88	**0.882**	599114	**0.855**
	526.97	865099	409.42	**0.777**	648552	**0.750**	405.71	**0.770**	655476	**0.758**
	710.50	1095457	686.97	0.967	1078849	0.985	676.04	0.952	1086018	0.991
o8_ar4_1	4411.54	6706259	5121.20	*1.161*	7496062	*1.118*	5044.01	*1.143*	7417370	*1.106*
	6285.83	8616144	3295.09	**0.524**	4727848	**0.549**	3337.85	**0.531**	4797459	**0.557**
	5463.33	8021477	3880.78	**0.710**	5749409	**0.717**	4049.91	**0.741**	5935186	**0.740**
o9_ar4_1	4717.44	6655360	7.03%	1.526	9256637	1.391	4276.50	**0.907**	6141642	**0.923**
	25.70%	6966391	9.65%	1.000	9341042	1.341	10.39%	1.000	9212450	1.322
	30.12%	6402740	19.23%	1.000	7530210	1.176	19.14%	1.000	7574677	1.183
oaer	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
oil2	5.85	2	5.82	0.996	2	1.000	5.91	1.009	2	1.000
	8.52	2	8.56	1.004	2	1.000	8.51	0.999	2	1.000
	9.15	2	9.16	1.001	2	1.000	9.29	1.014	2	1.000
ortez	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
pb302035	511.80%	2965	511.80%	1.000	2985	1.007	511.80%	1.000	2966	1.000
	515.07%	3151	515.07%	1.000	3155	1.001	515.07%	1.000	3147	0.999
	510.17%	2978	510.17%	1.000	2982	1.001	510.17%	1.000	2986	1.003
pb302055	451.64%	3299	453.42%	1.000	3282	0.995	453.42%	1.000	3276	0.993
	481.32%	3132	481.32%	1.000	3131	1.000	481.32%	1.000	3129	0.999
	444.71%	3631	445.46%	1.000	3670	1.010	445.46%	1.000	3670	1.010
pb302075	418.14%	3686	419.92%	1.000	3477	0.945	419.92%	1.000	3478	0.945
	387.51%	3528	396.36%	1.000	3650	1.034	396.98%	1.000	3640	1.031
	401.73%	3641	385.95%	1.000	3611	0.992	385.95%	1.000	3607	0.991
pb302095	122.73%	7823	115.59%	1.000	6815	0.873	115.59%	1.000	6837	0.876
	112.81%	7699	120.56%	1.000	8231	1.068	120.56%	1.000	8129	1.055
	120.77%	6045	111.97%	1.000	8055	1.327	111.97%	1.000	8036	1.324
pb351535	326.42%	3729	330.07%	1.000	3828	1.026	329.78%	1.000	3847	1.031
	394.91%	3185	394.91%	1.000	3186	1.000	394.91%	1.000	3185	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	335.95%	3691	335.68%	1.000	3681	0.997	335.68%	1.000	3689	0.999
pb351555	322.06%	3594	321.92%	1.000	3639	1.012	322.00%	1.000	3627	1.009
	345.21%	3470	345.12%	1.000	3471	1.000	345.21%	1.000	3458	0.997
	349.45%	3418	349.45%	1.000	3418	1.000	349.45%	1.000	3424	1.002
pb351575	391.15%	3891	393.17%	1.000	3484	0.898	393.17%	1.000	3499	0.902
	387.64%	3504	393.38%	1.000	3431	0.980	393.38%	1.000	3431	0.980
	411.37%	3361	406.90%	1.000	3349	0.997	406.90%	1.000	3349	0.997
pb351595	376.09%	3482	361.92%	1.000	3681	1.056	361.80%	1.000	3696	1.060
	357.62%	2888	348.79%	1.000	3538	1.218	348.79%	1.000	3538	1.218
	391.36%	3508	358.30%	1.000	3407	0.972	358.30%	1.000	3406	0.972
pedigree_ex1058	1347.50	175244	1445.15	*1.072*	174879	0.998	1446.56	*1.073*	174879	0.998
	627.29	116498	1074.92	*1.712*	162024	*1.390*	1076.85	*1.716*	162024	*1.390*
	1630.08	230650	1979.98	*1.215*	232095	1.006	1979.27	*1.214*	232095	1.006
pedigree_ex485	189.72	50947	202.68	*1.068*	55618	*1.092*	202.93	*1.069*	55618	*1.092*
	151.64	34260	165.19	*1.089*	32482	**0.948**	164.62	*1.085*	32482	**0.948**
	215.07	62883	251.25	*1.167*	67620	*1.075*	250.83	*1.166*	67620	*1.075*
pedigree_ex485_2	18.70	7609	20.37	*1.085*	6793	**0.894**	20.49	*1.091*	6793	**0.894**
	9.87	3163	11.32	*1.133*	4053	*1.273*	11.30	*1.132*	4053	*1.273*
	10.01	4034	11.19	*1.107*	4965	*1.225*	11.19	*1.107*	4965	*1.225*
pedigree_sim2000	3.91%	57138	2.62%	1.000	238068	4.161	2.62%	1.000	239446	4.185
	5.41%	58071	4.73%	1.000	59101	1.018	4.73%	1.000	59217	1.020
	2.18%	214770	4.00%	1.000	51360	0.239	4.00%	1.000	51208	0.239
pedigree_sim400	2.31%	1451061	2.16%	1.000	1981890	1.366	2.16%	1.000	1984112	1.367
	2.33%	1642100	2.15%	1.000	1759826	1.072	2.15%	1.000	1755789	1.069
	2.34%	1882378	1.91%	1.000	1757619	0.934	1.91%	1.000	1765490	0.938
pedigree_sp_top4_250	534.28	160235	493.07	**0.923**	145692	**0.909**	492.32	**0.922**	145692	**0.909**
	675.76	196918	588.58	**0.871**	162579	**0.826**	595.61	**0.882**	162579	**0.826**
	801.85	182745	729.14	**0.909**	201487	*1.103*	731.59	**0.912**	201487	*1.103*
pedigree_sp_top4_300	546.68	126874	798.35	*1.460*	148010	*1.166*	798.08	*1.459*	148010	*1.166*
	1369.99	289904	765.33	**0.559**	252628	**0.871**	763.44	**0.558**	252628	**0.871**
	1025.30	155124	1198.39	*1.169*	198405	*1.279*	1202.26	*1.172*	198405	*1.279*
pedigree_sp_top4_350tr	1285.83	320255	1548.85	*1.204*	449298	*1.403*	1551.36	*1.206*	449298	*1.403*
	1076.35	529979	967.92	**0.899**	299299	**0.565**	970.06	**0.901**	299299	**0.565**
	2718.11	433771	2043.09	**0.752**	415741	0.958	2042.40	**0.751**	415741	0.958

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
pedigree_sp_top5_200	1298.17	268863	1121.17	**0.864**	210920	**0.785**	1117.72	**0.861**	210920	**0.785**
	1296.13	255422	1985.96	*1.532*	376410	*1.473*	1987.51	*1.533*	376410	*1.473*
	1809.82	268037	1434.14	**0.793**	249012	**0.929**	1425.08	**0.788**	249012	**0.929**
pedigree_sp_top5_250	1997.95	208304	1093.05	**0.547**	205141	0.985	1099.78	**0.551**	205141	0.985
	961.67	183106	1754.16	*1.823*	265479	*1.450*	1761.97	*1.831*	265479	*1.450*
	1541.60	215353	868.20	**0.563**	193579	**0.899**	867.01	**0.563**	193579	**0.899**
pooling_epa1	0.05%	750134	0.05%	1.000	772411	1.030	4827.47	**0.671**	789231	*1.052*
pooling_epa2	∞	192161	∞	1.000	191201	0.995	∞	1.000	208715	1.086
	∞	253391	∞	1.000	254744	1.005	∞	1.000	290528	1.147
	∞	312227	∞	1.000	311937	0.999	∞	1.000	317119	1.016
pooling_epa3	∞	44450	∞	1.000	44588	1.003	∞	1.000	44672	1.005
	∞	50690	∞	1.000	50627	0.999	∞	1.000	50549	0.997
	∞	45636	∞	1.000	45402	0.995	∞	1.000	45512	0.997
portfol_buyin	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	57.38	20410	51.62	**0.901**	14862	**0.729**	51.84	**0.905**	14862	**0.729**
	41.65	14797	37.58	**0.905**	10964	**0.743**	37.71	**0.908**	10964	**0.743**
	69.53	25751	51.10	**0.739**	16301	**0.634**	51.02	**0.738**	16301	**0.634**
portfol_classical200_2	16.16%	253322	15.75%	1.000	245083	0.967	15.75%	1.000	245471	0.969
	14.56%	261749	14.62%	1.000	249268	0.952	14.62%	1.000	249261	0.952
	14.50%	261326	15.52%	1.000	247049	0.945	15.52%	1.000	248641	0.951
portfol_robust050_34	3.12	60	3.56	*1.107*	74	*1.087*	3.53	*1.100*	74	*1.087*
	2.03	34	2.83	*1.264*	28	0.955	2.82	*1.261*	28	0.955
	2.78	54	2.11	**0.823**	35	**0.877**	2.14	**0.831**	35	**0.877**
portfol_robust100_09	23.09	450	20.20	**0.880**	355	**0.827**	20.27	**0.883**	355	**0.827**
	24.13	329	19.87	**0.830**	269	**0.860**	19.91	**0.832**	269	**0.860**
	29.37	624	23.00	**0.790**	389	**0.675**	22.85	**0.785**	389	**0.675**
portfol_robust200_03	3.77%	44864	3.15%	1.000	39995	0.892	3.16%	1.000	39774	0.887
	3.70%	40109	3.40%	1.000	38048	0.949	3.40%	1.000	38032	0.948
	4.23%	41321	4.76%	1.000	38582	0.934	4.76%	1.000	38545	0.933
portfol_shortfall050_68	13.50	130	13.62	1.008	159	*1.126*	13.65	1.010	159	*1.126*
	7.04	153	9.41	*1.295*	287	*1.530*	9.36	*1.289*	287	*1.530*
	14.02	86	14.76	1.049	145	*1.317*	14.79	*1.051*	145	*1.317*
portfol_shortfall100_04	1337.22	56148	1322.82	0.989	49794	**0.887**	1327.03	0.992	49794	**0.887**
	1236.61	52046	1224.22	0.990	51721	0.994	1234.52	0.998	51721	0.994

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1297.55	51112	1206.07	**0.930**	49765	0.974	1202.72	**0.927**	49765	0.974
portfol_shortfall200_05	1.51%	72762	1.45%	1.000	84594	1.162	1.45%	1.000	84859	1.166
	1.51%	73572	1.39%	1.000	76716	1.043	1.39%	1.000	76868	1.045
	1.27%	76652	1.38%	1.000	74990	0.978	1.39%	1.000	74815	0.976
primary	∞	1935201	∞	1.000	1431623	0.740	∞	1.000	1078882	0.558
	∞	2226289	≥ 10000%	1.000	2348770	1.055	∞	1.000	2109835	0.948
prob02	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
prob03	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
procsel	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
procurement1large	372.91%	48481	372.91%	1.000	48579	1.002	372.91%	1.000	48579	1.002
	372.73%	51856	372.73%	1.000	52064	1.004	372.73%	1.000	52328	1.009
	370.00%	51558	370.00%	1.000	51504	0.999	370.00%	1.000	51338	0.996
procurement1mot	506.98%	744243	507.01%	1.000	743433	0.999	507.08%	1.000	742213	0.997
	488.93%	856715	489.14%	1.000	851893	0.994	489.16%	1.000	851238	0.994
	531.09%	628706	531.09%	1.000	628585	1.000	531.06%	1.000	629620	1.001
procurement2mot	1.82	48	1.96	1.050	49	1.007	1.94	1.043	49	1.007
	2.39	83	2.33	0.982	85	1.011	2.40	1.003	85	1.011
	3.62	62	3.64	1.004	55	0.957	3.68	1.013	55	0.957
product2	10.31	2	9.39	**0.919**	2	1.000	9.37	**0.917**	2	1.000
	3.87	1	4.11	1.049	1	1.000	4.13	*1.053*	1	1.000
	8.66	23	9.53	*1.090*	2	**0.829**	9.33	*1.069*	2	**0.829**
product	43.38	2651	44.46	1.024	1351	**0.527**	44.36	1.022	1351	**0.527**
	50.54	6966	20.29	**0.413**	853	**0.135**	20.38	**0.415**	853	**0.135**
	50.94	6940	51.63	1.013	4191	**0.610**	61.05	*1.195*	1674	**0.252**
qap	≥ 10000%	263789	≥ 10000%	1.000	248605	0.942	≥ 10000%	1.000	248433	0.942
	∞	288231	∞	1.000	244357	0.848	∞	1.000	243233	0.844
	≥ 10000%	267458	∞	1.000	237599	0.888	∞	1.000	239163	0.894
qapw	51.16%	44553	48.54%	1.000	46084	1.034	48.53%	1.000	47027	1.055

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	51.70%	50105	51.66%	1.000	48943	0.977	50.69%	1.000	52164	1.041
	51.09%	52901	50.85%	1.000	59156	1.118	49.52%	1.000	62559	1.182
qspp_0_10_0_1_10_1	66.13	23727	60.03	**0.909**	23248	0.980	60.41	**0.915**	23248	0.980
	65.91	27117	52.47	**0.799**	19657	**0.726**	52.32	**0.797**	19657	**0.726**
	72.47	26268	63.99	**0.885**	26207	0.998	64.52	**0.892**	26207	0.998
qspp_0_11_0_1_10_1	200.24	100851	174.56	**0.872**	96205	0.954	173.55	**0.867**	96205	0.954
	204.62	97827	181.04	**0.885**	92041	**0.941**	181.17	**0.886**	92041	**0.941**
	213.22	113147	206.43	0.968	108453	0.959	206.13	0.967	108453	0.959
qspp_0_12_0_1_10_1	568.79	303843	563.78	0.991	310298	1.021	564.44	0.992	310298	1.021
	642.24	325402	535.04	**0.833**	303981	**0.934**	536.37	**0.835**	303981	**0.934**
	639.32	321478	574.90	**0.899**	316954	0.986	581.27	**0.909**	316954	0.986
qspp_0_13_0_1_10_1	3050.48	1343163	2970.96	0.974	1335841	0.995	2988.13	0.980	1335841	0.995
	3156.21	1352649	2614.64	**0.828**	1249544	**0.924**	2627.58	**0.833**	1249544	**0.924**
	3247.11	1395696	2719.39	**0.838**	1247117	**0.894**	2714.70	**0.836**	1247117	**0.894**
qspp_0_14_0_1_10_1	42.79%	2583477	31.67%	1.000	3096830	1.199	32.35%	1.000	3061618	1.185
	44.88%	2528727	49.09%	1.000	2641447	1.045	49.26%	1.000	2630314	1.040
	51.82%	2402465	36.38%	1.000	3036363	1.264	36.35%	1.000	3037959	1.265
qspp_0_15_0_1_10_1	76.94%	1766570	63.86%	1.000	2288752	1.296	63.88%	1.000	2287387	1.295
	98.05%	1622191	91.24%	1.000	1924016	1.186	91.10%	1.000	1933831	1.192
	97.07%	1622614	72.93%	1.000	2049725	1.263	73.08%	1.000	2038206	1.256
radar-2000-10-a-6_lat_7	82.37	7	82.57	1.002	7	1.000	82.66	1.003	7	1.000
	85.77	7	85.49	0.997	7	1.000	85.25	0.994	7	1.000
	85.51	7	85.34	0.998	7	1.000	85.27	0.997	7	1.000
radar-3000-10-a-8_lat_7	170.86%	19098	170.86%	1.000	21927	1.147	170.86%	1.000	21896	1.146
	170.86%	18389	170.86%	1.000	20323	1.105	170.86%	1.000	20355	1.106
	170.86%	16732	170.86%	1.000	20484	1.223	170.86%	1.000	20466	1.222
ravempb	5.00	8	4.98	0.997	8	1.000	4.99	0.998	8	1.000
	5.35	8	5.40	1.008	8	1.000	5.33	0.997	8	1.000
	4.80	10	4.72	0.986	10	1.000	4.68	0.979	10	1.000
ringpack_10_1	3.95%	5047393	8.22%	1.000	4354224	0.863	8.22%	1.000	2908218	0.576
	3.95%	6193694	3.95%	1.000	3723333	0.601	3.95%	1.000	4136518	0.668
	3.95%	4996021	8.22%	1.000	3582335	0.717	8.22%	1.000	2847776	0.570
ringpack_10_2	8.22%	3868170	3.95%	1.000	3658193	0.946	8.22%	1.000	2376008	0.614
	3.95%	1884066	3.95%	1.000	3874654	2.056	3.95%	1.000	3766891	1.999

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	3.94%	4430920	3.95%	1.000	3489514	0.788	3.95%	1.000	3344842	0.755
ringpack_20_1	278.77%	1425726	53.86%	1.000	990688	0.695	278.77%	1.000	1069600	0.750
	36.44%	1504388	35.20%	1.000	1050493	0.698	218.46%	1.000	1064986	0.708
	218.46%	1238706	218.46%	1.000	1042324	0.841	278.77%	1.000	1150674	0.929
ringpack_20_2	73.38%	1162827	73.33%	1.000	955667	0.822	73.38%	1.000	1014713	0.873
	36.12%	1023677	19.75%	1.000	806006	0.787	15.75%	1.000	884481	0.864
	52.55%	908141	60.09%	1.000	885929	0.976	70.60%	1.000	914206	1.007
ringpack_20_3	400.00%	1214098	17.09%	1.000	986939	0.813	30.23%	1.000	902292	0.743
	56.53%	1026964	12.35%	1.000	982574	0.957	31.02%	1.000	882722	0.860
	400.00%	1098973	400.00%	1.000	1196218	1.088	23.31%	1.000	950041	0.864
ringpack_30_1	351.78%	345994	351.78%	1.000	310376	0.897	379.18%	1.000	324215	0.937
	379.18%	383460	379.18%	1.000	290507	0.758	313.18%	1.000	286755	0.748
	379.18%	350649	379.18%	1.000	302874	0.864	379.18%	1.000	305054	0.870
ringpack_30_2	223.95%	325360	191.18%	1.000	320025	0.984	189.57%	1.000	334415	1.028
	222.48%	133153	275.70%	1.000	125647	0.944	321.17%	1.000	131809	0.990
	313.18%	378044	313.18%	1.000	340630	0.901	263.16%	1.000	345502	0.914
risk2bpb	1.43	1	1.39	0.984	1	1.000	1.42	0.996	1	1.000
	1.08	1	1.09	1.005	1	1.000	1.11	1.014	1	1.000
	1.03	1	1.01	0.990	1	1.000	1.05	1.010	1	1.000
routingdelay_bigm	139.15	21901	73.02	**0.528**	10021	**0.460**	73.28	**0.530**	10021	**0.460**
	199.69	44013	72.94	**0.368**	14740	**0.336**	73.03	**0.369**	14740	**0.336**
	89.76	13978	57.25	**0.642**	9921	**0.712**	57.28	**0.642**	9921	**0.712**
routingdelay_proj	∞	614404	∞	1.000	613213	0.998	∞	1.000	612923	0.998
	∞	740492	∞	1.000	736189	0.994	∞	1.000	718940	0.971
	∞	736022	∞	1.000	727871	0.989	∞	1.000	732753	0.996
rsyn0805h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
rsyn0805m02h	1.51	3	1.50	0.996	3	1.000	1.52	1.004	3	1.000
	1.42	2	1.43	1.004	2	1.000	1.41	0.996	2	1.000
	1.24	2	1.23	0.996	2	1.000	1.25	1.004	2	1.000
rsyn0805m02m	7.43	1525	7.12	0.963	1369	**0.904**	7.18	0.970	1369	**0.904**
	8.51	1595	7.53	**0.897**	1395	**0.882**	7.66	**0.911**	1395	**0.882**
	12.91	4210	9.42	**0.749**	2604	**0.627**	9.31	**0.741**	2604	**0.627**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
rsyn0805m03h	1.66	2	1.64	0.992	2	1.000	1.61	0.981	2	1.000
	1.21	2	1.19	0.991	2	1.000	1.23	1.009	2	1.000
	1.12	2	1.09	0.986	2	1.000	1.12	1.000	2	1.000
rsyn0805m03m	17.00	1623	17.41	1.023	2015	*1.228*	17.47	1.026	2015	*1.228*
	10.36	1246	11.35	*1.087*	1402	*1.116*	11.27	*1.080*	1402	*1.116*
	13.85	1748	14.75	*1.061*	1628	**0.935**	14.75	*1.061*	1628	**0.935**
rsyn0805m04h	1.34	2	1.34	1.000	2	1.000	1.32	0.991	2	1.000
	2.69	2	2.74	1.014	2	1.000	2.64	0.986	2	1.000
	2.32	2	2.33	1.003	2	1.000	2.36	1.012	2	1.000
rsyn0805m04m	10.53	824	11.41	*1.076*	1032	*1.225*	11.49	*1.083*	1032	*1.225*
	12.81	1279	14.98	*1.157*	1209	**0.949**	15.02	*1.160*	1209	**0.949**
	7.67	707	8.34	*1.077*	920	*1.264*	8.32	*1.075*	920	*1.264*
rsyn0805m	2.57	106	2.41	0.955	106	1.000	2.47	0.972	106	1.000
	4.76	112	4.74	0.997	102	0.953	4.85	1.016	102	0.953
	1.41	162	1.38	0.988	145	**0.935**	1.38	0.988	145	**0.935**
rsyn0810h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
rsyn0810m02h	2.38	4	2.37	0.997	4	1.000	2.39	1.003	4	1.000
	4.29	24	4.32	1.006	24	1.000	4.25	0.992	24	1.000
	2.10	3	2.06	0.987	3	1.000	2.07	0.990	3	1.000
rsyn0810m02m	9.87	1984	9.68	0.983	1578	**0.805**	9.64	0.979	1578	**0.805**
	9.39	2237	12.65	*1.314*	3201	*1.412*	12.54	*1.303*	3201	*1.412*
	10.26	1926	10.06	0.982	2209	*1.140*	9.97	0.974	2209	*1.140*
rsyn0810m03h	3.67	4	3.67	1.000	4	1.000	3.62	0.989	4	1.000
	4.23	4	4.34	1.021	4	1.000	4.31	1.015	4	1.000
	4.40	4	4.35	0.991	4	1.000	4.39	0.998	4	1.000
rsyn0810m03m	16.99	3434	15.10	**0.895**	2328	**0.687**	14.88	**0.883**	2328	**0.687**
	10.84	1269	11.51	*1.057*	1614	*1.252*	11.54	*1.059*	1614	*1.252*
	19.87	3286	19.29	0.972	3037	**0.926**	19.25	0.970	3037	**0.926**
rsyn0810m04h	2.46	2	2.43	0.991	2	1.000	2.37	0.974	2	1.000
	3.84	2	3.83	0.998	2	1.000	3.86	1.004	2	1.000
	3.54	2	3.45	0.980	2	1.000	3.43	0.976	2	1.000
rsyn0810m04m	9.08	673	11.24	*1.214*	983	*1.401*	11.24	*1.214*	983	*1.401*

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	9.40	646	8.88	0.950	629	0.977	8.89	0.951	629	0.977
	12.26	1057	13.80	*1.116*	1402	*1.298*	13.69	*1.108*	1402	*1.298*
rsyn0810m	1.77	52	1.73	0.986	56	1.026	1.76	0.996	56	1.026
	1.77	29	1.74	0.989	29	1.000	1.78	1.004	29	1.000
	1.59	72	1.64	1.019	66	0.965	1.63	1.015	66	0.965
rsyn0815h	1.09	2	1.10	1.005	2	1.000	1.08	0.995	2	1.000
	1.31	4	1.27	0.983	4	1.000	1.29	0.991	4	1.000
	0.62	2	0.62	1.000	2	1.000	0.60	0.988	2	1.000
rsyn0815m02h	2.32	4	2.28	0.988	4	1.000	2.31	0.997	4	1.000
	1.77	2	1.84	1.025	2	1.000	1.81	1.014	2	1.000
	2.12	3	2.07	0.984	3	1.000	2.06	0.981	3	1.000
rsyn0815m02m	4.97	1116	8.68	*1.621*	1504	*1.319*	8.64	*1.615*	1504	*1.319*
	10.41	1579	8.25	**0.811**	1171	**0.757**	8.23	**0.809**	1171	**0.757**
	15.23	3964	10.82	**0.728**	1543	**0.404**	10.76	**0.725**	1543	**0.404**
rsyn0815m03h	5.73	22	5.84	1.016	22	1.000	5.92	1.028	22	1.000
	4.97	54	5.00	1.005	54	1.000	4.99	1.003	54	1.000
	4.87	50	4.87	1.000	50	1.000	4.88	1.002	50	1.000
rsyn0815m03m	17.78	2533	17.26	0.972	2407	0.952	17.21	0.970	2407	0.952
	15.71	1057	16.24	1.032	1349	*1.252*	16.25	1.032	1349	*1.252*
	26.41	3764	28.15	*1.063*	3217	**0.858**	27.93	*1.055*	3217	**0.858**
rsyn0815m04h	5.07	4	5.18	1.018	4	1.000	5.15	1.013	4	1.000
	5.05	3	5.17	1.020	3	1.000	5.14	1.015	3	1.000
	3.13	2	3.09	0.990	2	1.000	3.14	1.002	2	1.000
rsyn0815m04m	31.58	4068	30.58	0.969	3742	**0.922**	30.46	0.966	3742	**0.922**
	30.43	2654	31.64	1.038	2396	**0.906**	31.52	1.035	2396	**0.906**
	34.28	3469	39.49	*1.148*	3762	*1.082*	39.41	*1.145*	3762	*1.082*
rsyn0815m	1.74	46	1.75	1.004	50	1.027	1.75	1.004	50	1.027
	0.81	122	0.84	1.017	128	1.027	0.85	1.022	128	1.027
	1.02	53	1.01	0.995	57	1.026	0.97	0.975	57	1.026
rsyn0820h	2.31	5	2.28	0.991	5	1.000	2.27	0.988	5	1.000
	1.75	2	1.78	1.011	2	1.000	1.79	1.015	2	1.000
	1.88	3	1.84	0.986	3	1.000	1.85	0.990	3	1.000
rsyn0820m02h	2.88	7	2.80	0.979	7	1.000	2.84	0.990	7	1.000
	3.15	4	3.20	1.012	4	1.000	3.15	1.000	4	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	2.78	3	2.80	1.005	3	1.000	2.78	1.000	3	1.000
rsyn0820m02m	8.44	1552	10.38	*1.206*	1860	*1.186*	10.28	*1.195*	1860	*1.186*
	9.57	884	10.07	1.047	838	0.953	10.05	1.045	838	0.953
	10.18	1761	13.31	*1.280*	1973	*1.114*	13.37	*1.285*	1973	*1.114*
rsyn0820m03h	4.55	3	4.58	1.005	3	1.000	4.66	1.020	3	1.000
	5.18	2	5.22	1.006	2	1.000	5.20	1.003	2	1.000
	5.63	54	5.77	1.021	54	1.000	5.72	1.014	54	1.000
rsyn0820m03m	12.77	1993	12.07	**0.949**	1583	**0.804**	12.01	**0.945**	1583	**0.804**
	14.72	1928	17.52	*1.178*	2091	*1.080*	17.59	*1.183*	2091	*1.080*
	14.08	1518	12.83	**0.917**	1178	**0.790**	12.86	**0.919**	1178	**0.790**
rsyn0820m04h	7.39	5	7.42	1.004	5	1.000	7.37	0.998	5	1.000
	5.95	31	5.87	0.988	31	1.000	5.92	0.996	31	1.000
	2.97	2	2.94	0.992	2	1.000	3.00	1.008	2	1.000
rsyn0820m04m	54.42	7313	49.54	**0.912**	6450	**0.884**	49.32	**0.908**	6450	**0.884**
	47.03	5836	43.32	**0.923**	4879	**0.839**	43.37	**0.924**	4879	**0.839**
	50.71	6715	57.47	*1.131*	8520	*1.265*	57.34	*1.128*	8520	*1.265*
rsyn0820m	1.53	107	1.53	1.000	120	*1.063*	1.50	0.988	120	*1.063*
	1.22	200	1.19	0.986	183	**0.943**	1.23	1.005	183	**0.943**
	1.47	143	1.50	1.012	156	*1.053*	1.50	1.012	156	*1.053*
rsyn0830h	4.21	29	4.15	0.988	29	1.000	4.17	0.992	29	1.000
	2.81	37	2.82	1.003	37	1.000	2.74	0.982	37	1.000
	2.64	35	2.64	1.000	35	1.000	2.59	0.986	35	1.000
rsyn0830m02h	9.38	12	9.26	0.988	10	0.982	9.21	0.984	10	0.982
	4.81	51	4.83	1.003	51	1.000	4.89	1.014	51	1.000
	8.72	10	8.78	1.006	10	1.000	8.79	1.007	10	1.000
rsyn0830m02m	11.20	1331	10.17	**0.916**	1169	**0.887**	10.26	**0.923**	1169	**0.887**
	9.82	1199	13.38	*1.329*	2321	*1.864*	13.38	*1.329*	2321	*1.864*
	7.72	391	7.39	0.962	577	*1.379*	7.44	0.968	577	*1.379*
rsyn0830m03h	8.47	10	8.44	0.997	10	1.000	8.34	0.986	10	1.000
	11.71	33	11.51	0.984	33	1.000	11.67	0.997	33	1.000
	10.19	10	10.16	0.997	10	1.000	10.18	0.999	10	1.000
rsyn0830m03m	22.92	2380	21.12	**0.925**	2205	**0.929**	21.25	**0.930**	2205	**0.929**
	20.93	2077	26.51	*1.254*	2692	*1.282*	26.59	*1.258*	2692	*1.282*
	25.59	3098	23.61	**0.926**	1929	**0.634**	23.48	**0.921**	1929	**0.634**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
rsyn0830m04h	11.61	67	11.79	1.014	67	1.000	11.68	1.006	67	1.000
	14.58	63	14.55	0.998	63	1.000	14.66	1.005	63	1.000
	18.28	64	18.33	1.003	64	1.000	18.25	0.998	64	1.000
rsyn0830m04m	54.36	5196	52.05	0.958	6466	*1.240*	52.04	0.958	6466	*1.240*
	89.85	9648	70.45	**0.786**	7370	**0.766**	70.61	**0.788**	7370	**0.766**
	66.06	8293	58.65	**0.890**	4770	**0.580**	58.66	**0.890**	4770	**0.580**
rsyn0830m	1.13	116	1.08	0.977	110	0.972	1.12	0.995	110	0.972
	1.57	55	1.57	1.000	63	*1.052*	1.56	0.996	63	*1.052*
	1.02	84	1.13	*1.054*	102	*1.098*	1.11	1.045	102	*1.098*
rsyn0840h	0.98	3	1.01	1.015	3	1.000	1.01	1.015	3	1.000
	0.89	3	0.90	1.005	3	1.000	0.94	1.026	3	1.000
	1.09	18	1.10	1.005	18	1.000	1.13	1.019	18	1.000
rsyn0840m02h	3.02	4	2.94	0.980	4	1.000	2.99	0.993	4	1.000
	2.78	2	2.82	1.011	2	1.000	2.80	1.005	2	1.000
	5.25	6	5.28	1.005	6	1.000	5.25	1.000	6	1.000
rsyn0840m02m	13.17	1250	13.49	1.023	1138	**0.917**	13.59	1.030	1138	**0.917**
	10.59	703	12.43	*1.159*	853	*1.187*	12.33	*1.150*	853	*1.187*
	13.18	917	13.14	0.997	1017	*1.098*	12.97	0.985	1017	*1.098*
rsyn0840m03h	12.36	27	12.23	0.990	27	1.000	12.22	0.990	27	1.000
	11.08	80	11.12	1.003	80	1.000	11.20	1.010	80	1.000
	13.61	18	13.54	0.995	18	1.000	13.60	0.999	18	1.000
rsyn0840m03m	13.94	640	17.46	*1.236*	1096	*1.616*	17.37	*1.230*	1096	*1.616*
	14.47	693	14.80	1.021	569	**0.844**	14.96	1.032	569	**0.844**
	16.49	551	17.16	1.038	683	*1.203*	17.15	1.038	683	*1.203*
rsyn0840m04h	15.62	763	15.58	0.998	757	0.993	15.50	0.993	757	0.993
	17.42	377	17.43	1.001	377	1.000	17.47	1.003	377	1.000
rsyn0840m04m	78.17	11161	81.46	1.042	10504	**0.942**	81.15	1.038	10504	**0.942**
	99.32	13156	55.45	**0.563**	5690	**0.437**	55.45	**0.563**	5690	**0.437**
	109.63	10762	92.22	**0.843**	6327	**0.592**	91.72	**0.838**	6327	**0.592**
rsyn0840m	1.90	153	1.44	**0.841**	152	0.996	1.42	**0.834**	152	0.996
	1.16	90	1.35	*1.088*	136	*1.242*	1.32	*1.074*	136	*1.242*
	1.75	172	1.67	0.971	147	**0.908**	1.70	0.982	147	**0.908**
saa_2	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
sepasequ_complex	54.21%	2728633	44.72%	1.000	1214702	0.445	50.00%	1.000	1884068	0.690
	38.30%	1737508	28.71%	1.000	493509	0.284	20.72%	1.000	208499	0.120
	22.54%	366183	14.78%	1.000	243252	0.664	25.55%	1.000	1439856	3.931
sepasequ_convent	20.60	1022	20.64	1.002	1022	1.000	20.54	0.997	1022	1.000
	27.24	587	27.13	0.996	587	1.000	27.05	0.993	587	1.000
	30.66	1993	30.31	0.989	1993	1.000	30.35	0.990	1993	1.000
sfacloc1_2_80	85.82%	2435884	81.78%	1.000	2104867	0.864	82.56%	1.000	2171860	0.892
	45.34%	3031838	45.31%	1.000	3035153	1.001	44.57%	1.000	2992202	0.987
	86.73%	4133185	86.64%	1.000	4145916	1.003	76.54%	1.000	4275092	1.034
sfacloc1_2_90	54.45%	910187	54.41%	1.000	911322	1.001	54.72%	1.000	901430	0.990
	38.27%	3598354	38.07%	1.000	3561406	0.990	37.31%	1.000	3938743	1.095
	18.35%	8228726	18.25%	1.000	8346239	1.014	18.33%	1.000	8219209	0.999
sfacloc1_2_95	0.66%	9744003	0.60%	1.000	9518196	0.977	0.65%	1.000	9287523	0.953
	0.91%	9118300	5.23%	1.000	7902974	0.867	2.67%	1.000	8510524	0.933
	4.17%	8159494	3.11%	1.000	8481413	1.039	3.35%	1.000	8203648	1.005
sfacloc1_3_80	3765.08%	1555698	3765.08%	1.000	1558194	1.002	3116.52%	1.000	1479047	0.951
	1549.44%	1508448	1549.44%	1.000	1508515	1.000	2972.58%	1.000	1479727	0.981
	3615.89%	1689363	3607.35%	1.000	1695082	1.003	3610.27%	1.000	1692215	1.002
sfacloc1_3_90	364.51%	2601782	364.51%	1.000	2601685	1.000	364.61%	1.000	2600576	1.000
sfacloc1_3_95	60.32%	3662613	60.61%	1.000	3334989	0.911	60.64%	1.000	3329185	0.909
	898.50%	2167023	871.15%	1.000	2149906	0.992	986.33%	1.000	2104542	0.971
	929.88%	2067202	933.81%	1.000	2044696	0.989	936.11%	1.000	2037167	0.985
sfacloc2_2_80	8.11	1076	8.04	0.992	1076	1.000	8.07	0.996	1076	1.000
	6.41	1224	6.38	0.996	1224	1.000	6.34	0.991	1224	1.000
	6.98	845	6.99	1.001	845	1.000	6.53	**0.944**	891	1.049
sfacloc2_2_90	1.65	510	1.68	1.011	510	1.000	1.70	1.019	510	1.000
	1.35	295	1.36	1.004	295	1.000	1.38	1.013	295	1.000
sfacloc2_2_95	1.41	198	1.37	0.983	198	1.000	1.39	0.992	180	**0.940**
	0.99	170	0.96	0.985	170	1.000	1.03	1.020	170	1.000
	1.31	256	1.33	1.009	256	1.000	1.34	1.013	256	1.000
sfacloc2_3_80	33.30	8993	33.24	0.998	8987	0.999	32.15	0.966	6535	**0.730**
	22.27	6804	22.20	0.997	6794	0.999	21.67	0.974	5874	**0.865**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	25.80	5731	26.31	1.019	5713	0.997	31.99	*1.231*	7909	*1.374*
sfacloc2_3_90	8.02	2539	8.02	1.000	2539	1.000	6.63	**0.846**	2179	**0.864**
	10.23	3721	10.18	0.996	3721	1.000	12.76	*1.225*	4206	*1.127*
	6.81	2471	6.71	0.987	2471	1.000	5.78	**0.868**	1930	**0.790**
sfacloc2_3_95	7.08	2004	5.99	**0.865**	1889	**0.945**	5.94	**0.859**	1960	0.979
	3.56	1265	3.56	1.000	1265	1.000	3.27	**0.936**	1271	1.004
	2.90	1289	2.95	1.013	1289	1.000	3.37	*1.121*	1424	*1.097*
sfacloc2_4_80	51.78	21451	54.26	1.047	22954	*1.070*	46.20	**0.894**	21588	1.006
	59.04	27845	44.27	**0.754**	17847	**0.642**	49.33	**0.838**	22726	**0.817**
sfacloc2_4_90	10.89	3040	10.37	0.956	3138	1.031	10.22	**0.944**	3138	1.031
	12.84	4264	12.74	0.993	3869	**0.909**	12.83	0.999	4585	*1.074*
	12.67	4092	11.08	**0.884**	2809	**0.694**	12.44	0.983	3523	**0.864**
sfacloc2_4_95	6.82	2827	6.70	0.985	2782	0.985	6.52	0.962	2822	0.998
	6.33	3369	5.11	**0.834**	2100	**0.634**	5.62	**0.903**	2422	**0.727**
	5.45	3235	6.10	*1.101*	2939	**0.911**	6.18	*1.113*	2939	**0.911**
sjup2	2.44%	1	2.44%	1.000	1	1.000	2.44%	1.000	1	1.000
	2.63%	1	2.63%	1.000	1	1.000	2.63%	1.000	1	1.000
	2.63%	1	2.63%	1.000	1	1.000	2.63%	1.000	1	1.000
slay04h	1.44	33	1.47	1.012	32	0.992	1.50	1.025	32	0.992
	2.23	17	2.22	0.997	17	1.000	2.25	1.006	17	1.000
	6.35	14	6.33	0.997	14	1.000	6.25	0.986	14	1.000
slay04m	3.20	8	3.23	1.007	8	1.000	3.26	1.014	8	1.000
	3.78	12	3.81	1.006	12	1.000	3.78	1.000	12	1.000
	2.73	10	2.70	0.992	10	1.000	2.69	0.989	10	1.000
slay05h	2.73	136	3.26	*1.142*	169	*1.140*	3.25	*1.139*	169	*1.140*
	2.00	51	2.08	1.027	48	0.980	2.07	1.023	48	0.980
	2.54	101	2.29	**0.929**	85	**0.920**	2.32	**0.938**	85	**0.920**
slay05m	1.45	14	1.41	0.984	14	1.000	1.39	0.976	14	1.000
	1.17	12	1.23	1.028	14	1.018	1.20	1.014	14	1.018
	1.61	12	1.67	1.023	12	1.000	1.64	1.011	12	1.000
slay06h	12.27	37	12.35	1.006	29	**0.942**	12.27	1.000	29	**0.942**
	4.83	251	3.78	**0.820**	163	**0.749**	3.75	**0.815**	163	**0.749**
	15.01	39	14.89	0.993	33	0.957	14.95	0.996	33	0.957
slay06m	3.35	30	3.33	0.995	29	0.992	3.36	1.002	29	0.992

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	4.27	22	4.22	0.991	22	1.000	4.29	1.004	22	1.000
	3.48	18	3.45	0.993	14	0.966	3.40	0.982	14	0.966
slay07h	13.61	502	13.34	0.982	467	**0.942**	13.28	0.977	467	**0.942**
	14.44	548	15.17	1.047	430	**0.818**	15.06	1.040	430	**0.818**
	14.13	708	12.53	**0.894**	543	**0.796**	12.54	**0.895**	543	**0.796**
slay07m	2.35	55	2.49	1.042	44	**0.929**	2.43	1.024	44	**0.929**
	2.27	55	2.03	**0.927**	46	**0.942**	1.96	**0.905**	46	**0.942**
	2.21	51	2.24	1.009	51	1.000	2.18	0.991	51	1.000
slay08h	23.91	1103	21.04	**0.885**	1114	1.009	21.19	**0.891**	1114	1.009
	27.36	1428	27.46	1.004	1510	*1.054*	27.28	0.997	1510	*1.054*
	20.29	1046	19.86	0.980	806	**0.791**	19.83	0.978	806	**0.791**
slay08m	3.13	65	2.82	**0.925**	55	**0.939**	2.87	**0.937**	55	**0.939**
	3.53	123	3.55	1.004	124	1.004	3.47	0.987	124	1.004
	2.37	71	2.41	1.012	68	0.982	2.40	1.009	68	0.982
slay09h	49.60	4350	50.61	1.020	4076	**0.938**	50.64	1.021	4076	**0.938**
	34.57	1666	44.87	*1.290*	1321	**0.805**	44.83	*1.288*	1321	**0.805**
	45.73	2894	71.31	*1.547*	2422	**0.842**	71.20	*1.545*	2422	**0.842**
slay09m	4.68	141	4.67	0.998	161	*1.083*	4.56	0.979	161	*1.083*
	4.13	168	4.13	1.000	130	**0.858**	4.06	0.986	130	**0.858**
	4.72	123	5.13	*1.072*	103	**0.910**	5.22	*1.087*	103	**0.910**
slay10h	304.04	52296	199.52	**0.657**	25019	**0.479**	183.74	**0.606**	22975	**0.440**
	509.09	111289	341.74	**0.672**	63189	**0.568**	347.46	**0.683**	63835	**0.574**
	270.22	41205	178.01	**0.660**	19345	**0.471**	175.80	**0.652**	19280	**0.469**
slay10m	22.62	1760	21.46	0.951	1748	0.994	21.62	0.958	1748	0.994
	19.53	1997	19.63	1.005	1738	**0.876**	19.61	1.004	1738	**0.876**
	28.43	2001	27.48	0.968	2025	1.011	27.49	0.968	2025	1.011
smallinvDAXr1b010-011	0.50	102	0.50	1.000	100	0.990	0.50	1.000	100	0.990
	0.50	102	0.50	1.000	100	0.990	0.50	1.000	100	0.990
	0.50	102	0.50	1.000	100	0.990	0.50	1.000	100	0.990
smallinvDAXr1b020-022	0.50	76	0.50	1.000	86	*1.057*	0.50	1.000	86	*1.057*
	0.50	76	0.50	1.000	86	*1.057*	0.50	1.000	86	*1.057*
	0.50	76	0.50	1.000	86	*1.057*	0.50	1.000	86	*1.057*
smallinvDAXr1b050-055	0.50	292	0.50	1.000	259	**0.916**	0.50	1.000	259	**0.916**
	0.50	292	0.50	1.000	259	**0.916**	0.50	1.000	259	**0.916**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	292	0.50	1.000	259	**0.916**	0.50	1.000	259	**0.916**
smallinvDAXr1b100-110	0.50	408	0.73	*1.153*	686	*1.547*	0.75	*1.167*	686	*1.547*
	0.50	408	0.69	*1.127*	686	*1.547*	0.69	*1.127*	686	*1.547*
	0.50	408	0.71	*1.140*	686	*1.547*	0.73	*1.153*	686	*1.547*
smallinvDAXr1b150-165	0.68	812	0.71	1.018	766	**0.950**	0.72	1.024	766	**0.950**
	0.71	812	0.74	1.018	766	**0.950**	0.73	1.012	766	**0.950**
	0.73	812	0.71	0.988	766	**0.950**	0.74	1.006	766	**0.950**
smallinvDAXr1b200-220	0.50	202	0.63	*1.087*	462	*1.861*	0.63	*1.087*	462	*1.861*
	0.50	202	0.62	*1.080*	462	*1.861*	0.64	*1.093*	462	*1.861*
	0.52	202	0.61	*1.059*	462	*1.861*	0.63	*1.072*	462	*1.861*
smallinvDAXr2b010-011	0.50	90	0.50	1.000	88	0.989	0.50	1.000	88	0.989
	0.50	90	0.50	1.000	88	0.989	0.50	1.000	88	0.989
	0.50	90	0.50	1.000	88	0.989	0.50	1.000	88	0.989
smallinvDAXr2b020-022	0.50	94	0.50	1.000	114	*1.103*	0.50	1.000	114	*1.103*
	0.50	94	0.50	1.000	114	*1.103*	0.50	1.000	114	*1.103*
	0.50	94	0.50	1.000	114	*1.103*	0.50	1.000	114	*1.103*
smallinvDAXr2b050-055	0.50	191	0.50	1.000	278	*1.299*	0.50	1.000	278	*1.299*
	0.50	191	0.50	1.000	278	*1.299*	0.50	1.000	278	*1.299*
	0.50	191	0.50	1.000	278	*1.299*	0.50	1.000	278	*1.299*
smallinvDAXr2b100-110	0.50	315	0.57	1.047	551	*1.569*	0.59	*1.060*	551	*1.569*
	0.50	315	0.57	1.047	551	*1.569*	0.59	*1.060*	551	*1.569*
	0.50	315	0.60	*1.067*	551	*1.569*	0.60	*1.067*	551	*1.569*
smallinvDAXr2b150-165	0.57	552	0.72	*1.096*	812	*1.399*	0.74	*1.108*	812	*1.399*
	0.59	552	0.75	*1.101*	812	*1.399*	0.75	*1.101*	812	*1.399*
	0.61	552	0.72	*1.068*	812	*1.399*	0.77	*1.099*	812	*1.399*
smallinvDAXr2b200-220	0.61	480	0.71	*1.062*	733	*1.436*	0.71	*1.062*	733	*1.436*
	0.66	480	0.74	1.048	733	*1.436*	0.75	*1.054*	733	*1.436*
	0.62	480	0.69	1.043	733	*1.436*	0.73	*1.068*	733	*1.436*
smallinvDAXr3b010-011	0.50	101	0.50	1.000	90	**0.945**	0.50	1.000	90	**0.945**
	0.50	101	0.50	1.000	90	**0.945**	0.50	1.000	90	**0.945**
	0.50	101	0.50	1.000	90	**0.945**	0.50	1.000	90	**0.945**
smallinvDAXr3b020-022	0.50	110	0.50	1.000	115	1.024	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	115	1.024	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	115	1.024	0.50	1.000	115	1.024

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
smallinvDAXr3b050-055	0.50	130	0.50	1.000	167	*1.161*	0.50	1.000	167	*1.161*
	0.50	130	0.50	1.000	167	*1.161*	0.50	1.000	167	*1.161*
	0.50	130	0.50	1.000	167	*1.161*	0.50	1.000	167	*1.161*
smallinvDAXr3b100-110	0.50	322	0.55	1.033	496	*1.412*	0.58	*1.053*	496	*1.412*
	0.50	322	0.55	1.033	496	*1.412*	0.59	*1.060*	496	*1.412*
	0.50	322	0.59	*1.060*	496	*1.412*	0.56	1.040	496	*1.412*
smallinvDAXr3b150-165	0.61	518	0.63	1.012	682	*1.265*	0.65	1.025	682	*1.265*
	0.58	518	0.65	1.044	682	*1.265*	0.63	1.032	682	*1.265*
	0.64	518	0.61	0.982	682	*1.265*	0.66	1.012	682	*1.265*
smallinvDAXr3b200-220	0.57	380	0.71	*1.089*	470	*1.188*	0.69	*1.076*	470	*1.188*
	0.61	380	0.70	*1.056*	470	*1.188*	0.69	1.050	470	*1.188*
	0.62	380	0.70	1.049	470	*1.188*	0.75	*1.080*	470	*1.188*
smallinvDAXr4b010-011	0.50	101	0.50	1.000	90	**0.945**	0.50	1.000	90	**0.945**
	0.50	101	0.50	1.000	90	**0.945**	0.50	1.000	90	**0.945**
	0.50	101	0.50	1.000	90	**0.945**	0.50	1.000	90	**0.945**
smallinvDAXr4b020-022	0.50	110	0.50	1.000	115	1.024	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	115	1.024	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	115	1.024	0.50	1.000	115	1.024
smallinvDAXr4b050-055	0.50	132	0.50	1.000	168	*1.155*	0.50	1.000	168	*1.155*
	0.50	132	0.50	1.000	168	*1.155*	0.50	1.000	168	*1.155*
	0.50	132	0.50	1.000	168	*1.155*	0.50	1.000	168	*1.155*
smallinvDAXr4b100-110	0.50	331	0.66	*1.107*	532	*1.466*	0.74	*1.160*	486	*1.360*
	0.50	331	0.66	*1.107*	532	*1.466*	0.70	*1.133*	486	*1.360*
	0.50	331	0.59	*1.060*	532	*1.466*	0.70	*1.133*	486	*1.360*
smallinvDAXr4b150-165	0.57	562	0.65	*1.051*	682	*1.181*	0.66	*1.057*	682	*1.181*
	0.57	562	0.67	*1.064*	682	*1.181*	0.65	*1.051*	682	*1.181*
	0.59	562	0.64	1.031	682	*1.181*	0.67	*1.050*	682	*1.181*
smallinvDAXr4b200-220	0.60	380	0.69	*1.056*	470	*1.188*	0.69	*1.056*	470	*1.188*
	0.59	380	0.70	*1.069*	470	*1.188*	0.70	*1.069*	470	*1.188*
	0.62	380	0.67	1.031	470	*1.188*	0.71	*1.056*	470	*1.188*
smallinvDAXr5b010-011	0.50	148	0.50	1.000	88	**0.758**	0.50	1.000	88	**0.758**
	0.50	148	0.50	1.000	88	**0.758**	0.50	1.000	88	**0.758**
	0.50	148	0.50	1.000	88	**0.758**	0.50	1.000	88	**0.758**
smallinvDAXr5b020-022	0.50	110	0.50	1.000	115	1.024	0.50	1.000	115	1.024

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Table E.2: Detailed computational results on nonconvex instances of MINLPLIB.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	110	0.50	1.000	115	1.024	0.50	1.000	115	1.024
	0.50	110	0.50	1.000	115	1.024	0.50	1.000	115	1.024
smallinvDAXr5b050-055	0.50	132	0.50	1.000	168	*1.155*	0.50	1.000	168	*1.155*
	0.50	132	0.50	1.000	168	*1.155*	0.50	1.000	168	*1.155*
	0.50	132	0.50	1.000	168	*1.155*	0.50	1.000	168	*1.155*
smallinvDAXr5b100-110	0.50	331	0.65	*1.100*	532	*1.466*	0.70	*1.133*	486	*1.360*
	0.50	331	0.65	*1.100*	532	*1.466*	0.68	*1.120*	486	*1.360*
	0.50	331	0.63	*1.087*	532	*1.466*	0.71	*1.140*	486	*1.360*
smallinvDAXr5b150-165	0.60	562	0.60	1.000	692	*1.196*	0.65	1.031	692	*1.196*
	0.59	562	0.62	1.019	692	*1.196*	0.68	*1.057*	692	*1.196*
	0.55	562	0.64	*1.058*	692	*1.196*	0.62	1.045	692	*1.196*
smallinvDAXr5b200-220	0.59	380	0.68	*1.057*	470	*1.188*	0.73	*1.088*	470	*1.188*
	0.62	380	0.74	*1.074*	470	*1.188*	0.71	*1.056*	470	*1.188*
	0.57	380	0.69	*1.076*	470	*1.188*	0.69	*1.076*	470	*1.188*
smallinvSNPr1b010-011	5.76	826	5.89	1.019	881	*1.059*	5.83	1.010	881	*1.059*
	5.67	826	5.91	1.036	881	*1.059*	5.81	1.021	881	*1.059*
	5.63	826	5.87	1.036	881	*1.059*	5.92	1.044	881	*1.059*
smallinvSNPr1b020-022	168.51	52018	232.61	*1.378*	74667	*1.435*	231.63	*1.372*	74667	*1.435*
	169.30	52018	230.67	*1.360*	74667	*1.435*	230.87	*1.362*	74667	*1.435*
	169.00	52018	231.31	*1.367*	74667	*1.435*	231.16	*1.366*	74667	*1.435*
smallinvSNPr1b050-055	4104.98	660385	819.31%	1.754	945731	1.432	820.90%	1.754	942157	1.427
	4096.49	660385	819.31%	1.757	945731	1.432	819.31%	1.757	945731	1.432
	4123.20	660385	819.18%	1.746	945988	1.432	820.90%	1.746	942157	1.427
smallinvSNPr1b100-110	∞	440398	∞	1.000	406119	0.922	∞	1.000	404417	0.918
	∞	438007	∞	1.000	405266	0.925	∞	1.000	405266	0.925
	∞	438543	∞	1.000	405564	0.925	∞	1.000	405542	0.925
smallinvSNPr1b150-165	∞	317018	∞	1.000	296624	0.936	∞	1.000	295725	0.933
	∞	317392	∞	1.000	296602	0.935	∞	1.000	295971	0.933
	∞	318011	∞	1.000	296679	0.933	∞	1.000	295725	0.930
smallinvSNPr1b200-220	∞	201592	∞	1.000	239506	1.188	∞	1.000	238855	1.185
	∞	202031	∞	1.000	239971	1.188	∞	1.000	238868	1.182
	∞	202539	∞	1.000	239698	1.183	∞	1.000	239698	1.183
smallinvSNPr2b010-011	4.30	498	4.07	0.957	428	**0.883**	4.10	0.962	428	**0.883**
	4.34	498	4.08	0.951	428	**0.883**	4.08	0.951	428	**0.883**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	4.30	498	4.07	0.957	428	**0.883**	4.08	0.958	428	**0.883**
smallinvSNPr2b020-022	29.68	7513	44.25	*1.475*	12322	*1.632*	45.13	*1.504*	12322	*1.632*
	29.73	7513	44.63	*1.485*	12322	*1.632*	44.48	*1.480*	12322	*1.632*
	29.84	7513	44.48	*1.475*	12322	*1.632*	44.55	*1.477*	12322	*1.632*
smallinvSNPr2b050-055	393.41	78269	1278.81	*3.245*	238093	*3.039*	1281.25	*3.251*	238093	*3.039*
	394.12	78269	1274.61	*3.228*	238093	*3.039*	1276.50	*3.233*	238093	*3.039*
	394.66	78269	1280.49	*3.239*	238093	*3.039*	1285.59	*3.252*	238093	*3.039*
smallinvSNPr2b100-110	∞	347615	∞	1.000	438355	1.261	∞	1.000	439049	1.263
	∞	346516	∞	1.000	437995	1.264	∞	1.000	439049	1.267
	∞	347449	∞	1.000	437995	1.261	∞	1.000	439618	1.265
smallinvSNPr2b150-165	31.88%	96769	3195.18	**0.444**	123108	*1.272*	3192.67	**0.444**	119996	*1.240*
	31.78%	97510	3178.61	**0.442**	123108	*1.262*	3204.32	**0.445**	119996	*1.230*
	31.86%	96880	3195.02	**0.444**	123108	*1.270*	3182.71	**0.442**	119996	*1.238*
smallinvSNPr2b200-220	69.89%	52496	63.02%	1.000	61314	1.168	70.07%	1.000	53091	1.011
	70.02%	52341	62.99%	1.000	61462	1.174	70.16%	1.000	53051	1.014
	69.83%	52676	62.93%	1.000	61654	1.170	70.22%	1.000	52790	1.002
smallinvSNPr3b010-011	3.87	113	3.95	1.016	139	*1.122*	3.95	1.016	139	*1.122*
	3.85	113	3.91	1.012	139	*1.122*	3.92	1.014	139	*1.122*
	3.92	113	3.88	0.992	139	*1.122*	3.89	0.994	139	*1.122*
smallinvSNPr3b020-022	6.70	564	6.11	**0.923**	377	**0.718**	6.15	**0.929**	377	**0.718**
	6.70	564	6.09	**0.921**	377	**0.718**	6.14	**0.927**	377	**0.718**
	6.80	564	6.11	**0.912**	377	**0.718**	6.09	**0.909**	377	**0.718**
smallinvSNPr3b050-055	78.90	6221	173.34	*2.182*	30996	*4.919*	174.49	*2.196*	30996	*4.919*
	78.77	6221	173.69	*2.190*	30996	*4.919*	174.80	*2.204*	30996	*4.919*
	78.75	6221	174.52	*2.201*	30996	*4.919*	174.20	*2.197*	30996	*4.919*
smallinvSNPr3b100-110	126.62	3962	424.60	*3.335*	24382	*6.027*	428.26	*3.364*	24382	*6.027*
	126.55	3962	426.84	*3.354*	24382	*6.027*	427.47	*3.359*	24382	*6.027*
	126.33	3962	425.51	*3.350*	24382	*6.027*	428.45	*3.373*	24382	*6.027*
smallinvSNPr3b150-165	∞	573926	∞	1.000	318384	0.555	∞	1.000	317469	0.553
	∞	568528	∞	1.000	320175	0.563	∞	1.000	318384	0.560
	∞	569523	∞	1.000	318573	0.559	∞	1.000	317743	0.558
smallinvSNPr3b200-220	∞	560586	∞	1.000	469525	0.838	∞	1.000	469525	0.838
	∞	561649	∞	1.000	469312	0.836	∞	1.000	469949	0.837
	∞	561095	∞	1.000	469742	0.837	∞	1.000	469525	0.837

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
smallinvSNPr4b010-011	3.38	191	3.45	1.016	214	*1.079*	3.46	1.018	214	*1.079*
	3.35	191	3.40	1.011	214	*1.079*	3.46	1.025	214	*1.079*
	3.39	191	3.50	1.025	214	*1.079*	3.48	1.021	214	*1.079*
smallinvSNPr4b020-022	8.64	333	7.13	**0.843**	272	**0.859**	7.12	**0.842**	272	**0.859**
	8.77	333	7.10	**0.829**	272	**0.859**	7.13	**0.832**	272	**0.859**
	8.80	333	7.10	**0.827**	272	**0.859**	7.08	**0.824**	272	**0.859**
smallinvSNPr4b050-055	22.16	1998	23.39	*1.053*	2471	*1.225*	23.43	*1.055*	2471	*1.225*
	22.33	1998	23.52	*1.051*	2471	*1.225*	23.57	*1.053*	2471	*1.225*
	22.13	1998	23.44	*1.057*	2471	*1.225*	23.47	*1.058*	2471	*1.225*
smallinvSNPr4b100-110	126.03	8139	128.44	1.019	7040	**0.867**	128.19	1.017	7040	**0.867**
	126.79	8139	128.05	1.010	7040	**0.867**	128.13	1.010	7040	**0.867**
	126.58	8139	127.99	1.011	7040	**0.867**	127.48	1.007	7040	**0.867**
smallinvSNPr4b150-165	155.34	4688	224.64	*1.443*	6391	*1.356*	224.24	*1.441*	6391	*1.356*
	155.11	4688	224.21	*1.443*	6391	*1.356*	224.91	*1.447*	6391	*1.356*
	155.96	4688	225.16	*1.441*	6391	*1.356*	224.34	*1.436*	6391	*1.356*
smallinvSNPr4b200-220	389.93	30337	3073.46	*7.864*	223360	*7.342*	3056.43	*7.821*	223360	*7.342*
	385.59	30337	3041.85	*7.871*	223360	*7.342*	3057.14	*7.911*	223360	*7.342*
	386.97	30337	3049.26	*7.862*	223360	*7.342*	3044.34	*7.849*	223360	*7.342*
smallinvSNPr5b010-011	1.99	87	2.00	1.003	99	*1.064*	2.04	1.017	99	*1.064*
	2.02	87	2.02	1.000	99	*1.064*	2.00	0.993	99	*1.064*
	1.99	87	1.99	1.000	99	*1.064*	2.01	1.007	99	*1.064*
smallinvSNPr5b020-022	4.57	89	4.15	**0.925**	88	0.995	4.17	**0.928**	88	0.995
	4.58	89	4.17	**0.927**	88	0.995	4.20	**0.932**	88	0.995
	4.58	89	4.13	**0.919**	88	0.995	4.17	**0.927**	88	0.995
smallinvSNPr5b050-055	32.88	554	14.27	**0.451**	229	**0.503**	13.94	**0.441**	229	**0.503**
	33.17	554	14.10	**0.442**	229	**0.503**	14.25	**0.446**	229	**0.503**
	33.02	554	14.18	**0.446**	229	**0.503**	14.12	**0.444**	229	**0.503**
smallinvSNPr5b100-110	39.55	758	50.05	*1.259*	1662	*2.054*	50.40	*1.268*	1662	*2.054*
	39.54	758	50.43	*1.269*	1662	*2.054*	50.15	*1.262*	1662	*2.054*
	39.65	758	50.21	*1.260*	1662	*2.054*	50.13	*1.258*	1662	*2.054*
smallinvSNPr5b150-165	103.40	4693	92.70	**0.898**	4675	0.996	92.48	**0.895**	4675	0.996
	104.58	4693	92.46	**0.885**	4675	0.996	92.24	**0.883**	4675	0.996
	104.54	4693	92.49	**0.886**	4675	0.996	93.64	**0.897**	4675	0.996
smallinvSNPr5b200-220	613.12	37721	1906.62	*3.106*	116700	*3.088*	1905.67	*3.105*	116700	*3.088*

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	615.52	37721	1894.21	*3.074*	116700	*3.088*	1909.87	*3.099*	116700	*3.088*
	612.15	37721	1902.05	*3.104*	116700	*3.088*	1889.76	*3.084*	116700	*3.088*
sonet17v4	956.75	6401	813.46	**0.850**	5703	**0.893**	812.99	**0.850**	5703	**0.893**
	1133.93	6947	1138.76	1.004	6947	1.000	1138.04	1.004	6947	1.000
	1227.93	8187	1229.42	1.001	8187	1.000	1233.53	1.005	8187	1.000
sonet18v6	1028.31	4755	984.95	0.958	4489	**0.945**	998.32	0.971	4772	1.004
	1112.88	4969	1076.64	0.967	4815	0.970	1082.18	0.972	4815	0.970
	1298.14	7123	1239.29	0.955	6327	**0.890**	1271.63	0.980	6485	**0.912**
sonet19v5	8.74%	30740	7164.64	0.995	30475	0.991	10.03%	1.000	31672	1.030
	6521.83	26431	7002.25	*1.074*	26919	1.018	6786.66	1.041	25991	0.983
	6936.58	27697	10.80%	1.038	30059	1.085	6542.40	**0.943**	25907	**0.936**
sonet20v6	2533.89	3937	2358.04	**0.931**	3214	**0.821**	2325.14	**0.918**	3359	**0.857**
	1926.22	2477	2206.94	*1.146*	3060	*1.226*	1971.04	1.023	2660	*1.071*
	1703.92	2454	1730.33	1.015	2538	1.033	1658.47	0.973	2383	0.972
sonet21v6	5.44%	20003	5.24%	1.000	21281	1.064	5.24%	1.000	21252	1.062
	5.38%	20654	5.23%	1.000	22370	1.083	5.23%	1.000	22393	1.084
	5.11%	27944	5.23%	1.000	24124	0.864	5.23%	1.000	24181	0.866
sonet22v4	7.02%	15275	6.38%	1.000	16670	1.091	6.38%	1.000	16754	1.096
	7.36%	11771	6.93%	1.000	11824	1.004	6.93%	1.000	11799	1.002
	6.87%	16366	7.17%	1.000	14141	0.865	7.17%	1.000	14183	0.867
sonet22v5	192.03%	2465	174.58%	1.000	2498	1.013	214.84%	1.000	2235	0.910
	210.42%	2709	167.02%	1.000	2408	0.893	224.15%	1.000	2615	0.967
	213.94%	2195	201.02%	1.000	2252	1.025	203.55%	1.000	2242	1.020
sonet23v6	20.26%	4660	25.98%	1.000	1673	0.372	22.36%	1.000	2335	0.512
	18.49%	8134	19.67%	1.000	8732	1.073	19.92%	1.000	8054	0.990
	20.02%	8300	20.11%	1.000	8691	1.047	22.23%	1.000	8387	1.010
sonet24v2	384.74	91	388.66	1.010	91	1.000	385.93	1.003	91	1.000
	151.05	26	152.15	1.007	26	1.000	153.05	1.013	26	1.000
	307.92	63	307.99	1.000	63	1.000	307.39	0.998	63	1.000
sonet24v5	204.66%	1172	217.43%	1.000	1155	0.987	215.43%	1.000	1188	1.013
	218.74%	1554	199.50%	1.000	1481	0.956	201.64%	1.000	1553	0.999
	191.32%	1288	236.86%	1.000	1408	1.086	185.49%	1.000	1211	0.945
sonet25v5	11.04%	5574	9.62%	1.000	4322	0.779	9.62%	1.000	4322	0.779
	10.58%	3533	10.65%	1.000	2975	0.846	10.65%	1.000	2975	0.846

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	10.74%	5828	11.10%	1.000	6156	1.055	11.10%	1.000	6115	1.048
sonet25v6	287.81%	710	360.91%	1.000	784	1.091	345.22%	1.000	753	1.053
	331.63%	843	317.34%	1.000	878	1.037	294.47%	1.000	821	0.977
	329.58%	927	369.19%	1.000	958	1.030	323.80%	1.000	977	1.049
sonetgr17	86.28%	115239	88.94%	1.000	121341	1.053	84.03%	1.000	122794	1.066
	100.46%	128372	93.82%	1.000	137501	1.071	104.23%	1.000	130803	1.019
	96.35%	125420	90.98%	1.000	145527	1.160	94.52%	1.000	124632	0.994
space25	∞	299	∞	1.000	5128	13.103	∞	1.000	3642	9.378
	∞	590	∞	1.000	96	0.284	∞	1.000	96	0.284
	∞	6649	∞	1.000	813	0.135	∞	1.000	4048	0.615
space25a	∞	975	∞	1.000	2131	2.075	∞	1.000	2266	2.201
	∞	850	∞	1.000	1098	1.261	∞	1.000	1098	1.261
	∞	1419	∞	1.000	411	0.336	∞	1.000	411	0.336
space960	∞	1681	∞	1.000	1720	1.022	∞	1.000	1733	1.029
	∞	1830	∞	1.000	2098	1.139	∞	1.000	2103	1.141
	∞	1409	∞	1.000	1513	1.069	∞	1.000	1509	1.066
spectra2	7.94	16	7.99	1.006	16	1.000	8.01	1.008	16	1.000
	8.15	16	8.22	1.008	16	1.000	8.23	1.009	16	1.000
	9.04	14	9.05	1.001	14	1.000	9.07	1.003	14	1.000
sporttournament06	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
sporttournament08	0.83	119	0.84	1.005	147	*1.128*	0.85	1.011	147	*1.128*
	0.81	119	0.85	1.022	147	*1.128*	0.85	1.022	147	*1.128*
	0.84	119	0.85	1.005	147	*1.128*	0.82	0.989	147	*1.128*
sporttournament10	2.06	582	2.03	0.990	511	**0.896**	2.06	1.000	511	**0.896**
	2.05	582	2.02	0.990	511	**0.896**	2.06	1.003	511	**0.896**
	2.06	582	2.07	1.003	511	**0.896**	2.05	0.997	511	**0.896**
sporttournament12	6.39	868	6.27	0.984	995	*1.131*	6.27	0.984	995	*1.131*
	6.31	868	6.32	1.001	995	*1.131*	6.27	0.995	995	*1.131*
	6.30	868	6.25	0.993	995	*1.131*	6.23	0.990	995	*1.131*
sporttournament14	6.59%	45151	6.60%	1.000	44923	0.995	6.59%	1.000	45113	0.999
	6.59%	45104	6.59%	1.000	45125	1.000	6.59%	1.000	45049	0.999
	6.59%	45113	6.59%	1.000	45111	1.000	6.60%	1.000	44979	0.997

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
sporttournament16	51.50	4785	36.47	**0.714**	3958	**0.831**	36.41	**0.713**	3958	**0.831**
	51.36	4785	36.52	**0.717**	3958	**0.831**	36.59	**0.718**	3958	**0.831**
	51.50	4785	36.37	**0.712**	3958	**0.831**	36.42	**0.713**	3958	**0.831**
sporttournament18	510.88	137834	518.27	1.014	135577	0.984	518.72	1.015	135577	0.984
	511.38	137834	518.27	1.013	135577	0.984	518.27	1.013	135577	0.984
	511.04	137834	518.14	1.014	135577	0.984	519.02	1.016	135577	0.984
sporttournament20	2.17%	2351103	6466.71	**0.898**	1813679	**0.771**	6460.43	**0.897**	1813679	**0.771**
	2.17%	2348794	6479.30	**0.900**	1813679	**0.772**	6458.81	**0.897**	1813679	**0.772**
	2.17%	2347432	6456.04	**0.897**	1813679	**0.773**	6454.92	**0.897**	1813679	**0.773**
sporttournament22	5.32%	1537654	5.68%	1.000	1536902	1.000	5.69%	1.000	1531222	0.996
	5.63%	1440663	5.68%	1.000	1542278	1.071	5.68%	1.000	1538475	1.068
	5.48%	1951952	5.81%	1.000	1701963	0.872	5.81%	1.000	1702525	0.872
sporttournament24	5.40%	862891	5.40%	1.000	816160	0.946	5.41%	1.000	811384	0.940
	5.40%	858321	5.41%	1.000	812317	0.946	5.41%	1.000	813457	0.948
	5.40%	863017	5.41%	1.000	812471	0.941	5.41%	1.000	814105	0.943
sporttournament26	10.75%	608618	10.28%	1.000	367025	0.603	10.28%	1.000	366288	0.602
	10.75%	606985	10.12%	1.000	346294	0.571	10.12%	1.000	346839	0.571
	10.75%	476331	10.19%	1.000	388254	0.815	10.19%	1.000	389803	0.818
sporttournament28	9.23%	321005	7.87%	1.000	236471	0.737	7.86%	1.000	237829	0.741
	9.23%	319591	7.87%	1.000	236311	0.739	7.86%	1.000	237281	0.743
	12.58%	153540	9.39%	1.000	256372	1.669	9.39%	1.000	256497	1.670
sporttournament30	17.17%	68994	18.52%	1.000	576993	8.352	18.52%	1.000	575782	8.335
	17.17%	69052	18.56%	1.000	566631	8.195	18.57%	1.000	562751	8.139
	17.17%	68963	18.60%	1.000	536866	7.775	18.60%	1.000	537762	7.788
sporttournament32	19.66%	30001	18.67%	1.000	348061	11.566	18.68%	1.000	344732	11.456
	17.62%	340411	16.73%	1.000	265114	0.779	16.71%	1.000	271474	0.798
	19.90%	30138	18.52%	1.000	326464	10.800	18.52%	1.000	325302	10.761
sporttournament34	21.11%	356789	20.68%	1.000	273716	0.767	20.68%	1.000	273833	0.768
	21.11%	356934	21.19%	1.000	251792	0.706	21.19%	1.000	250385	0.702
	21.11%	356064	20.68%	1.000	273895	0.769	20.68%	1.000	273431	0.768
sporttournament36	19.21%	152553	20.71%	1.000	166374	1.091	20.71%	1.000	166875	1.094
	21.18%	178601	20.70%	1.000	166926	0.935	20.70%	1.000	167494	0.938
	19.74%	153285	19.64%	1.000	163185	1.065	19.64%	1.000	163562	1.067
sporttournament38	23.18%	102614	25.05%	1.000	80197	0.782	25.04%	1.000	80434	0.784

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	23.67%	93218	25.04%	1.000	80371	0.862	25.03%	1.000	80907	0.868
	22.91%	90508	25.03%	1.000	80987	0.895	25.03%	1.000	80956	0.895
sporttournament40	25.33%	79631	27.94%	1.000	98245	1.233	27.95%	1.000	97696	1.227
	26.12%	73557	26.72%	1.000	76119	1.035	26.72%	1.000	75629	1.028
	27.42%	43930	26.70%	1.000	95859	2.179	26.70%	1.000	95983	2.182
sporttournament42	25.07%	64991	24.29%	1.000	82659	1.271	24.29%	1.000	82501	1.269
	25.09%	82718	24.39%	1.000	36689	0.444	24.39%	1.000	36981	0.448
	24.27%	71148	23.66%	1.000	78708	1.106	23.66%	1.000	78711	1.106
sporttournament44	30.57%	76561	27.74%	1.000	67324	0.880	27.74%	1.000	67753	0.885
	30.25%	65687	27.44%	1.000	69041	1.051	27.45%	1.000	68593	1.044
	30.60%	74416	28.31%	1.000	73058	0.982	28.31%	1.000	73218	0.984
sporttournament46	28.20%	56660	29.43%	1.000	61351	1.083	29.43%	1.000	61330	1.082
	28.73%	75611	28.40%	1.000	59984	0.794	28.41%	1.000	59600	0.789
	28.41%	29622	25.66%	1.000	29232	0.987	25.67%	1.000	29179	0.985
sporttournament48	28.07%	46021	27.97%	1.000	41242	0.896	27.97%	1.000	41141	0.894
	26.70%	20130	28.21%	1.000	58612	2.902	28.20%	1.000	58783	2.911
	27.16%	40615	27.84%	1.000	45226	1.113	27.84%	1.000	45115	1.111
sporttournament50	32.68%	48557	30.90%	1.000	44422	0.915	30.90%	1.000	44259	0.912
	31.80%	46384	29.84%	1.000	62138	1.339	29.85%	1.000	61883	1.333
	30.54%	54639	31.52%	1.000	49577	0.908	31.52%	1.000	49701	0.910
spring	0.50	34	0.50	1.000	34	1.000	0.50	1.000	34	1.000
	0.50	34	0.50	1.000	34	1.000	0.50	1.000	34	1.000
	0.50	34	0.50	1.000	34	1.000	0.50	1.000	34	1.000
squfl010-025	447.81	333	128.70	**0.289**	319	0.968	129.08	**0.290**	319	0.968
	129.87	317	125.75	0.969	307	0.976	125.66	0.968	307	0.976
	479.67	319	160.58	**0.336**	303	0.962	160.68	**0.336**	303	0.962
squfl010-040	48.66%	63	79.04%	1.000	47	0.902	79.04%	1.000	47	0.902
	78.47%	39	52.55%	1.000	43	1.029	52.55%	1.000	43	1.029
	96.93%	28	77.58%	1.000	36	1.062	77.58%	1.000	36	1.062
squfl010-040persp	5.93	1	5.83	0.986	1	1.000	5.91	0.997	1	1.000
	5.93	1	5.84	0.987	1	1.000	5.80	0.981	1	1.000
	6.14	1	5.98	0.978	1	1.000	6.01	0.982	1	1.000
squfl010-080	104.65%	64	104.65%	1.000	64	1.000	104.65%	1.000	64	1.000
	147.22%	47	147.22%	1.000	47	1.000	147.22%	1.000	47	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	120.36%	52	120.36%	1.000	52	1.000	120.36%	1.000	52	1.000
squfl015-060	68.31%	219	77.14%	1.000	137	0.743	77.14%	1.000	137	0.743
	82.77%	172	85.22%	1.000	156	0.941	85.22%	1.000	156	0.941
	87.75%	175	82.91%	1.000	152	0.916	82.91%	1.000	152	0.916
squfl015-080	117.21%	81	117.21%	1.000	96	1.083	117.21%	1.000	96	1.083
	122.52%	68	110.57%	1.000	96	1.167	110.57%	1.000	96	1.167
	118.90%	91	123.43%	1.000	82	0.953	124.74%	1.000	81	0.948
squfl020-040	125.09%	111	109.47%	1.000	162	1.242	109.47%	1.000	162	1.242
	65.98%	139	75.30%	1.000	145	1.025	75.30%	1.000	145	1.025
	75.33%	159	93.30%	1.000	138	0.919	93.30%	1.000	138	0.919
squfl020-050	163.59%	155	163.34%	1.000	147	0.969	163.34%	1.000	146	0.965
	105.06%	167	102.76%	1.000	177	1.037	102.76%	1.000	176	1.034
	103.67%	189	114.50%	1.000	98	0.685	114.50%	1.000	98	0.685
squfl020-150	286.08%	1	286.08%	1.000	1	1.000	286.08%	1.000	1	1.000
	284.20%	1	284.20%	1.000	1	1.000	284.20%	1.000	1	1.000
	438.58%	1	438.71%	1.000	1	1.000	438.58%	1.000	1	1.000
squfl025-025	4461.31	5081	5234.78	*1.173*	5175	1.018	5213.17	*1.168*	5175	1.018
	4604.72	5427	4258.81	**0.925**	4436	**0.821**	4260.43	**0.925**	4436	**0.821**
squfl025-030	33.01%	2849	20.46%	1.000	2554	0.900	20.46%	1.000	2554	0.900
	36.91%	2491	23.40%	1.000	3267	1.299	22.08%	1.000	3314	1.318
	35.20%	2272	17.20%	1.000	3157	1.373	15.76%	1.000	3218	1.399
squfl025-040	110.13%	569	119.63%	1.000	480	0.867	119.16%	1.000	493	0.886
	126.03%	758	134.09%	1.000	483	0.679	134.09%	1.000	481	0.677
	112.79%	595	144.29%	1.000	290	0.561	144.29%	1.000	290	0.561
squfl030-100	261.20%	5	261.20%	1.000	5	1.000	261.20%	1.000	5	1.000
	257.69%	3	257.69%	1.000	3	1.000	257.69%	1.000	3	1.000
	261.22%	5	261.22%	1.000	5	1.000	261.22%	1.000	5	1.000
squfl030-150	615.85%	1	615.85%	1.000	1	1.000	615.85%	1.000	1	1.000
	610.50%	1	610.50%	1.000	1	1.000	610.50%	1.000	1	1.000
	578.71%	1	578.44%	1.000	1	1.000	578.44%	1.000	1	1.000
squfl040-080	263.46%	6	263.46%	1.000	6	1.000	263.46%	1.000	6	1.000
	414.56%	8	414.56%	1.000	8	1.000	414.56%	1.000	8	1.000
	273.30%	6	273.30%	1.000	6	1.000	273.30%	1.000	6	1.000
sssd08-04	9.94	18996	10.57	*1.058*	19073	1.004	10.45	1.047	19073	1.004

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	10.84	21122	10.31	0.955	20728	0.981	10.39	0.962	20728	0.981
	11.52	21722	11.20	0.974	21188	0.976	11.36	0.987	21188	0.976
sssd08-04persp	8.98	16666	9.17	1.019	16666	1.000	8.83	0.985	16666	1.000
	9.40	18506	9.58	1.017	18506	1.000	9.60	1.019	18506	1.000
	9.65	17423	9.90	1.023	17423	1.000	9.84	1.018	17423	1.000
sssd12-05	3.23%	12723887	4585.38	**0.637**	9080544	**0.714**	4590.89	**0.638**	9080544	**0.714**
	6279.63	11344673	4598.26	**0.732**	8257726	**0.728**	4641.69	**0.739**	8257726	**0.728**
	6292.13	10621401	4183.60	**0.665**	7850120	**0.739**	4218.90	**0.671**	7850120	**0.739**
sssd12-05persp	2.90%	12707892	2.90%	1.000	12688561	0.998	2.95%	1.000	12585090	0.990
	3.53%	11804394	3.58%	1.000	11751271	0.995	3.59%	1.000	11741549	0.995
	3.62%	12382303	3.65%	1.000	12270685	0.991	3.68%	1.000	12164895	0.982
sssd15-04	9.62%	4699876	9.63%	1.000	4590638	0.977	9.63%	1.000	4575491	0.974
	9.80%	4687665	10.27%	1.000	3476300	0.742	10.28%	1.000	3472290	0.741
	9.12%	6271631	9.54%	1.000	4700095	0.749	9.54%	1.000	4692150	0.748
sssd15-04persp	9.66%	4660267	9.66%	1.000	4655885	0.999	9.66%	1.000	4667607	1.002
	9.60%	3246577	9.61%	1.000	3228657	0.994	9.61%	1.000	3236146	0.997
	10.34%	4429787	10.34%	1.000	4449143	1.004	10.35%	1.000	4424206	0.999
sssd15-06	21.15%	4882716	20.19%	1.000	5162082	1.057	20.19%	1.000	5162161	1.057
	19.64%	5315021	19.60%	1.000	5273476	0.992	19.60%	1.000	5261959	0.990
	20.66%	3782018	20.00%	1.000	4057915	1.073	20.00%	1.000	4040497	1.068
sssd15-06persp	19.77%	3514660	19.46%	1.000	4632572	1.318	19.47%	1.000	4599326	1.309
	19.62%	3829182	18.89%	1.000	5383925	1.406	18.89%	1.000	5398364	1.410
	19.53%	3865144	19.96%	1.000	3776371	0.977	19.96%	1.000	3777789	0.977
sssd15-08	17.05%	6021881	16.45%	1.000	7784970	1.293	16.45%	1.000	7723518	1.283
	17.10%	6780030	16.67%	1.000	7429088	1.096	16.67%	1.000	7425711	1.095
	17.02%	6688263	16.39%	1.000	7571929	1.132	16.39%	1.000	7625056	1.140
sssd15-08persp	16.91%	5080567	16.72%	1.000	4926481	0.970	16.73%	1.000	4903315	0.965
	16.59%	4877459	16.27%	1.000	5023372	1.030	16.27%	1.000	5006138	1.026
	16.27%	4802730	16.27%	1.000	4930711	1.027	16.27%	1.000	4923691	1.025
sssd16-07	16.34%	4928361	15.96%	1.000	5425514	1.101	15.96%	1.000	5427623	1.101
	16.46%	4969603	15.91%	1.000	5683511	1.144	15.91%	1.000	5691725	1.145
	16.24%	5174249	15.85%	1.000	5330357	1.030	15.85%	1.000	5341330	1.032
sssd16-07persp	16.29%	3280317	16.30%	1.000	3267544	0.996	16.29%	1.000	3278482	0.999
	15.81%	4131779	15.94%	1.000	4117293	0.996	15.94%	1.000	4106294	0.994

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	16.30%	4262899	16.30%	1.000	4300106	1.009	16.30%	1.000	4284402	1.005
sssd18-06	16.19%	2980222	16.26%	1.000	3248189	1.090	16.27%	1.000	3227339	1.083
	16.40%	3608497	15.75%	1.000	3120211	0.865	15.75%	1.000	3126025	0.866
	17.05%	3471056	16.39%	1.000	3682901	1.061	16.39%	1.000	3684873	1.062
sssd18-06persp	16.19%	1667473	16.19%	1.000	1681005	1.008	16.19%	1.000	1681005	1.008
	16.08%	1934599	16.07%	1.000	1985522	1.026	16.07%	1.000	1984630	1.026
	16.31%	1882656	16.31%	1.000	1894518	1.006	16.31%	1.000	1897859	1.008
sssd18-08	30.10%	5140728	28.65%	1.000	4932274	0.959	28.65%	1.000	4929314	0.959
	29.15%	5000594	27.65%	1.000	5925608	1.185	27.65%	1.000	5938116	1.187
	29.08%	4855505	28.42%	1.000	5939454	1.223	28.42%	1.000	5940088	1.223
sssd18-08persp	28.56%	3522615	28.44%	1.000	2768022	0.786	28.44%	1.000	2762021	0.784
	28.67%	3256501	28.47%	1.000	2721052	0.836	28.47%	1.000	2724599	0.837
	28.52%	3635479	28.40%	1.000	3563832	0.980	28.73%	1.000	2834391	0.780
sssd20-04	17.70%	2690820	17.64%	1.000	2734596	1.016	17.64%	1.000	2746662	1.021
	18.25%	4005453	18.41%	1.000	3320126	0.829	18.41%	1.000	3321120	0.829
	18.02%	3372152	18.28%	1.000	3498028	1.037	18.27%	1.000	3508189	1.040
sssd20-04persp	16.10%	1383131	16.10%	1.000	1383764	1.000	16.10%	1.000	1386045	1.002
	15.93%	1444610	16.21%	1.000	1417868	0.981	16.21%	1.000	1416756	0.981
	16.41%	1506606	16.41%	1.000	1494748	0.992	16.41%	1.000	1506206	1.000
sssd20-08	17.40%	3830078	16.91%	1.000	3851442	1.006	16.91%	1.000	3859414	1.008
	16.31%	3776591	16.46%	1.000	4088987	1.083	16.46%	1.000	4075112	1.079
	16.88%	3437432	16.58%	1.000	3818790	1.111	16.58%	1.000	3807854	1.108
sssd20-08persp	16.23%	2034117	16.25%	1.000	2203728	1.083	16.25%	1.000	2209960	1.086
	15.87%	2406408	15.87%	1.000	2403480	0.999	15.87%	1.000	2398859	0.997
	16.27%	1944331	15.97%	1.000	2267035	1.166	15.97%	1.000	2254214	1.159
sssd22-08	18.13%	3866790	18.34%	1.000	3026969	0.783	18.34%	1.000	3027035	0.783
	17.28%	3036051	17.14%	1.000	3261502	1.074	17.14%	1.000	3256963	1.073
	17.50%	3472333	17.60%	1.000	2885184	0.831	17.60%	1.000	2882080	0.830
sssd22-08persp	17.42%	2033453	17.42%	1.000	2027991	0.997	17.42%	1.000	2030021	0.998
	17.34%	1830194	17.67%	1.000	1798917	0.983	17.67%	1.000	1793980	0.980
	17.27%	1700274	17.48%	1.000	2020736	1.188	17.48%	1.000	2009886	1.182
sssd25-04	23.08%	3471234	23.03%	1.000	4640274	1.337	23.03%	1.000	4614788	1.329
	22.10%	1977139	22.04%	1.000	2381072	1.204	22.04%	1.000	2369309	1.198
	23.32%	2556967	23.21%	1.000	2555729	1.000	23.21%	1.000	2559515	1.001

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
sssd25-04persp	21.28%	1463300	21.29%	1.000	1522558	1.040	21.30%	1.000	1518423	1.038
	20.95%	1535486	20.99%	1.000	1527874	0.995	20.98%	1.000	1531861	0.998
	21.15%	1544843	21.15%	1.000	1542828	0.999	21.15%	1.000	1540592	0.997
sssd25-08	15.37%	2575266	15.03%	1.000	2591507	1.006	15.03%	1.000	2585280	1.004
	14.87%	2377275	14.91%	1.000	2770803	1.166	14.91%	1.000	2761979	1.162
	15.01%	2647388	14.94%	1.000	2524270	0.953	14.94%	1.000	2531302	0.956
sssd25-08persp	14.58%	1716834	14.58%	1.000	1725530	1.005	14.58%	1.000	1721738	1.003
	14.35%	1810462	14.54%	1.000	1674815	0.925	14.54%	1.000	1678126	0.927
	14.37%	1623602	14.38%	1.000	1600393	0.986	14.37%	1.000	1619853	0.998
st_e13	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_e14	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
st_e15	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_e27	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_e29	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_e31	2.84	575	2.76	0.979	575	1.000	2.76	0.979	575	1.000
	3.04	595	3.12	1.020	595	1.000	3.05	1.002	595	1.000
	2.95	601	2.95	1.000	601	1.000	3.01	1.015	601	1.000
st_e35	21.57	6981	33.61	*1.533*	13043	*1.856*	22.34	1.034	6861	0.983
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
st_e40	0.50	26	0.50	1.000	26	1.000	0.50	1.000	26	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_miqp2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_miqp3	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_miqp4	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_miqp5	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test1	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
	0.50	0	0.50	1.000	0	1.000	0.50	1.000	0	1.000
st_test2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test3	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test4	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test5	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test6	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test8	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
st_testgr1	0.50	14	0.50	1.000	16	1.018	0.50	1.000	16	1.018
	0.50	28	0.50	1.000	18	**0.922**	0.50	1.000	18	**0.922**
	0.50	28	0.50	1.000	18	**0.922**	0.50	1.000	18	**0.922**
st_testgr3	0.50	4	0.50	1.000	4	1.000	0.50	1.000	4	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_testph4	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
stockcycle	101.88	10397	116.51	*1.142*	11605	*1.115*	116.10	*1.138*	11605	*1.115*
	94.75	7441	220.85	*2.317*	16870	*2.250*	221.26	*2.321*	16870	*2.250*
	126.58	10920	140.64	*1.110*	11728	*1.073*	141.32	*1.116*	11728	*1.073*
super3t	57.67%	164	57.67%	1.000	164	1.000	57.67%	1.000	164	1.000
	61.89%	802	61.89%	1.000	802	1.000	61.89%	1.000	887	1.094
	65.07%	150	65.07%	1.000	150	1.000	65.07%	1.000	150	1.000
supplychainp1_020306	0.70	4	0.68	0.988	4	1.000	0.68	0.988	4	1.000
	0.72	5	0.72	1.000	5	1.000	0.73	1.006	5	1.000
	0.67	4	0.68	1.006	4	1.000	0.66	0.994	4	1.000
supplychainp1_022020	345.88	45652	510.65	*1.475*	112854	*2.469*	516.48	*1.492*	112854	*2.469*
	426.80	89871	479.31	*1.123*	90491	1.007	481.66	*1.128*	90491	1.007
	303.51	23315	465.15	*1.531*	46131	*1.974*	465.92	*1.533*	46131	*1.974*
supplychainp1_030510	3.91	1084	3.96	1.010	1084	1.000	3.97	1.012	1084	1.000
	2.94	471	1.96	**0.751**	168	**0.469**	2.00	**0.761**	168	**0.469**
	2.85	758	1.56	**0.665**	142	**0.282**	1.55	**0.662**	142	**0.282**
supplychainp1_053050	47.03%	21024	47.45%	1.000	28616	1.359	47.42%	1.000	28821	1.369
	41.57%	32277	44.32%	1.000	30961	0.959	44.32%	1.000	31021	0.961
	43.76%	33380	38.24%	1.000	33445	1.002	38.24%	1.000	33441	1.002
supplychainr1_020306	1.78	4	1.77	0.996	4	1.000	1.80	1.007	4	1.000
	1.65	4	1.62	0.989	4	1.000	1.61	0.985	4	1.000
	2.77	4	2.75	0.995	4	1.000	2.75	0.995	4	1.000
supplychainr1_022020	67.85	10993	68.22	1.005	10993	1.000	68.58	1.011	10993	1.000
	0.35%	7239502	0.35%	1.000	7175424	0.991	0.35%	1.000	7145272	0.987
	0.35%	7592051	0.35%	1.000	7487381	0.986	0.35%	1.000	7447762	0.981
supplychainr1_030510	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
supplychainr1_053050	20.98%	165663	21.32%	1.000	211100	1.274	21.29%	1.000	214404	1.294
	24.24%	235870	27.23%	1.000	132353	0.561	27.33%	1.000	129772	0.550
	25.79%	108023	19.69%	1.000	237900	2.201	19.69%	1.000	238489	2.207
syn05h	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn05m02h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn05m02m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn05m03h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn05m03m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn05m04h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn05m04m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn05m	0.66	2	0.61	0.970	2	1.000	0.66	1.000	2	1.000
	0.89	2	0.92	1.016	2	1.000	0.88	0.995	2	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
syn10h	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn10m02h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000

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Table E.2: Detailed computational results on nonconvex instances of MINLPLIB.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
syn10m02m	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn10m03h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.69	3	0.64	0.970	3	1.000	0.62	0.959	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn10m03m	0.78	3	0.76	0.989	3	1.000	0.77	0.994	3	1.000
	0.87	3	0.86	0.995	3	1.000	0.85	0.989	3	1.000
	0.60	2	0.61	1.006	2	1.000	0.59	0.994	2	1.000
syn10m04h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.63	2	0.63	1.000	2	1.000	0.59	0.975	2	1.000
	0.53	2	0.50	0.980	2	1.000	0.53	1.000	2	1.000
syn10m04m	1.10	4	1.10	1.000	4	1.000	1.12	1.010	4	1.000
	0.82	4	0.83	1.005	4	1.000	0.82	1.000	4	1.000
	0.56	3	0.59	1.019	3	1.000	0.58	1.013	3	1.000
syn10m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m02h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m02m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m03h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m03m	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m04h	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.56	2	0.57	1.006	2	1.000	0.59	1.019	2	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn15m04m	0.64	2	0.65	1.006	2	1.000	0.66	1.012	2	1.000
	1.01	2	1.00	0.995	2	1.000	1.00	0.995	2	1.000
	0.87	2	0.85	0.989	2	1.000	0.88	1.005	2	1.000
syn15m	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
syn20h	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn20m02h	0.53	2	0.51	0.987	2	1.000	0.50	0.980	2	1.000
	0.54	2	0.50	0.974	2	1.000	0.51	0.981	2	1.000
	0.84	2	0.84	1.000	2	1.000	0.82	0.989	2	1.000
syn20m02m	0.65	2	0.65	1.000	2	1.000	0.65	1.000	2	1.000
	0.57	2	0.58	1.006	2	1.000	0.55	0.987	2	1.000
	0.79	3	0.78	0.994	3	1.000	0.77	0.989	3	1.000
syn20m03h	0.55	1	0.53	0.987	1	1.000	0.54	0.994	1	1.000
	0.63	1	0.64	1.006	1	1.000	0.65	1.012	1	1.000
	0.53	1	0.53	1.000	1	1.000	0.51	0.987	1	1.000
syn20m03m	0.88	2	0.86	0.989	2	1.000	0.90	1.011	2	1.000
	1.16	2	1.18	1.009	2	1.000	1.18	1.009	2	1.000
	1.11	4	1.11	1.000	4	1.000	1.15	1.019	4	1.000
syn20m04h	1.24	2	1.22	0.991	2	1.000	1.15	0.960	2	1.000
	0.66	1	0.67	1.006	1	1.000	0.64	0.988	1	1.000
	0.93	1	0.89	0.979	1	1.000	0.96	1.016	1	1.000
syn20m04m	1.23	2	1.28	1.022	2	1.000	1.28	1.022	2	1.000
	2.00	2	2.00	1.000	2	1.000	1.98	0.993	2	1.000
	1.03	2	1.04	1.005	2	1.000	1.01	0.990	2	1.000
syn20m	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn30h	1.16	3	1.14	0.991	3	1.000	1.18	1.009	3	1.000
	0.86	19	0.84	0.989	19	1.000	0.85	0.995	19	1.000
	0.91	7	0.84	0.963	5	0.981	0.87	0.979	5	0.981

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
syn30m02h	1.38	47	1.41	1.013	47	1.000	1.36	0.992	47	1.000
	1.89	12	1.82	0.976	10	0.982	1.76	0.955	10	0.982
	1.91	27	1.90	0.997	27	1.000	1.84	0.976	27	1.000
syn30m02m	1.97	8	1.95	0.993	8	1.000	2.03	1.020	8	1.000
	2.32	9	2.32	1.000	9	1.000	2.38	1.018	9	1.000
	1.33	4	1.31	0.991	4	1.000	1.33	1.000	4	1.000
syn30m03h	2.47	30	2.56	1.026	30	1.000	2.55	1.023	30	1.000
	2.29	6	2.36	1.021	8	1.019	2.34	1.015	8	1.019
	2.30	63	2.31	1.003	63	1.000	2.28	0.994	63	1.000
syn30m03m	2.60	6	2.63	1.008	6	1.000	2.66	1.017	6	1.000
	2.16	8	2.14	0.994	8	1.000	2.13	0.991	8	1.000
	2.41	4	2.40	0.997	4	1.000	2.46	1.015	4	1.000
syn30m04h	3.61	153	3.58	0.993	153	1.000	3.60	0.998	153	1.000
	4.55	50	4.56	1.002	50	1.000	4.52	0.995	50	1.000
	3.10	24	3.05	0.988	24	1.000	3.06	0.990	24	1.000
syn30m04m	1.94	3	1.94	1.000	3	1.000	1.94	1.000	3	1.000
	2.35	6	2.30	0.985	6	1.000	2.32	0.991	6	1.000
	2.32	3	2.33	1.003	3	1.000	2.40	1.024	3	1.000
syn30m	0.82	4	0.81	0.995	4	1.000	0.80	0.989	4	1.000
	0.57	2	0.60	1.019	2	1.000	0.57	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
syn40h	1.33	12	1.29	0.983	11	0.991	1.28	0.979	11	0.991
	1.01	4	0.99	0.990	4	1.000	1.00	0.995	4	1.000
	0.96	46	0.95	0.995	46	1.000	0.95	0.995	46	1.000
syn40m02h	3.91	6	3.94	1.006	6	1.000	3.91	1.000	6	1.000
	1.62	124	1.62	1.000	124	1.000	1.63	1.004	124	1.000
	1.54	103	1.61	1.028	103	1.000	1.57	1.012	103	1.000
syn40m02m	2.28	4	2.28	1.000	4	1.000	2.26	0.994	4	1.000
	1.47	4	1.42	0.980	4	1.000	1.47	1.000	4	1.000
	2.18	17	2.21	1.009	17	1.000	2.22	1.013	17	1.000
syn40m03h	3.96	127	3.84	0.976	127	1.000	3.95	0.998	127	1.000
	4.20	216	4.25	1.010	216	1.000	4.23	1.006	216	1.000
	3.20	120	3.14	0.986	120	1.000	3.25	1.012	120	1.000
syn40m03m	2.64	6	2.70	1.016	4	0.981	2.61	0.992	4	0.981

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	2.69	4	2.70	1.003	4	1.000	2.67	0.995	4	1.000
	6.02	10	6.01	0.999	10	1.000	5.97	0.993	10	1.000
syn40m04h	8.16	109	8.26	1.011	109	1.000	8.17	1.001	109	1.000
	6.28	114	6.32	1.005	114	1.000	6.22	0.992	114	1.000
	6.17	353	6.09	0.989	353	1.000	6.16	0.999	353	1.000
syn40m04m	5.84	38	5.90	1.009	38	1.000	5.80	0.994	38	1.000
	6.25	12	6.31	1.008	12	1.000	6.45	1.028	12	1.000
	6.93	14	6.96	1.004	14	1.000	6.94	1.001	14	1.000
syn40m	0.66	3	0.68	1.012	3	1.000	0.67	1.006	3	1.000
	0.79	3	0.78	0.994	3	1.000	0.77	0.989	3	1.000
	0.80	4	0.85	1.028	4	1.000	0.86	1.033	4	1.000
synheat	2.90%	1419752	2.31%	1.000	1259809	0.887	1.42%	1.000	2036148	1.434
	1.27%	14675604	1.21%	1.000	9554803	0.651	1.13%	1.000	17596795	1.199
	1.13%	7638984	1.08%	1.000	6177958	0.809	1.12%	1.000	4427165	0.580
synthes1	0.62	3	0.63	1.006	3	1.000	0.63	1.006	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
synthes2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
synthes3	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
tanksize	3.94	2301	3.77	0.966	1871	**0.821**	3.73	0.957	1871	**0.821**
	5.78	2789	5.56	0.968	2291	**0.828**	5.58	0.971	2291	**0.828**
	4.85	2271	4.78	0.988	2031	**0.899**	4.82	0.995	2031	**0.899**
telecomsp_metro	21.75%	2340	18.74%	1.000	2824	1.198	18.74%	1.000	2823	1.198
	18.85%	2255	24.22%	1.000	1386	0.631	24.22%	1.000	1380	0.628
	20.98%	743	16.23%	1.000	1964	2.448	16.23%	1.000	1961	2.445
telecomsp_njlata	6.61%	1568	6.82%	1.000	1145	0.746	6.82%	1.000	1145	0.746
	7.60%	1881	6.69%	1.000	2098	1.110	6.69%	1.000	2098	1.110
	6.40%	2725	12.61%	1.000	261	0.128	12.61%	1.000	261	0.128
telecomsp_nor_sun	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
telecomsp_pacbell	1.96%	1543	1.19%	1.000	5630	3.488	1.19%	1.000	5645	3.497
	0.62%	7562	1.43%	1.000	2816	0.381	1.43%	1.000	2815	0.380
	1.50%	3879	0.79%	1.000	4124	1.062	0.79%	1.000	4125	1.062
tln12	1144.44%	82786	1067.90%	1.000	98964	1.195	1106.17%	1.000	104302	1.260
	1156.79%	76811	1095.06%	1.000	107198	1.395	1067.90%	1.000	117817	1.533
	1054.32%	89996	1075.31%	1.000	117674	1.307	1097.53%	1.000	112371	1.248
tln2	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
tln4	1.49	1603	1.52	1.012	1759	*1.092*	2.22	*1.293*	2692	*1.639*
	1.97	2048	1.96	0.997	2026	0.990	1.85	0.960	1998	0.977
	1.91	2368	1.61	**0.897**	1836	**0.784**	1.58	**0.887**	1754	**0.751**
tln5	26.44	30447	26.50	1.002	31134	1.022	26.21	0.992	29695	0.975
	99.76	88674	118.67	*1.188*	93992	*1.060*	119.53	*1.196*	92306	1.041
	62.44	65953	49.24	**0.792**	48502	**0.736**	49.07	**0.789**	48041	**0.729**
tln6	77.88%	217429	90.34%	1.000	240056	1.104	102.46%	1.000	193465	0.890
	141.93%	244129	146.23%	1.000	248840	1.019	141.18%	1.000	256846	1.052
	145.11%	209270	139.78%	1.000	183269	0.876	134.33%	1.000	182209	0.871
tln7	295.31%	169336	306.28%	1.000	221660	1.309	307.31%	1.000	221886	1.310
	309.35%	170150	312.62%	1.000	261412	1.536	346.99%	1.000	295341	1.735
	288.35%	173123	308.91%	1.000	228484	1.320	316.58%	1.000	278898	1.611
tloss	0.50	23	0.50	1.000	30	*1.057*	0.50	1.000	30	*1.057*
	0.50	36	0.50	1.000	30	0.956	0.50	1.000	30	0.956
	0.56	72	0.72	*1.103*	178	*1.616*	0.71	*1.096*	178	*1.616*
tls12	∞	74102	∞	1.000	77458	1.045	∞	1.000	76827	1.037
	∞	119756	∞	1.000	115232	0.962	∞	1.000	111195	0.929
	∞	101189	∞	1.000	99497	0.983	∞	1.000	94526	0.934
tls2	0.50	17	0.50	1.000	15	0.983	0.50	1.000	15	0.983
	0.50	17	0.50	1.000	15	0.983	0.50	1.000	15	0.983
	0.50	17	0.50	1.000	15	0.983	0.50	1.000	15	0.983
tls4	14.51	6554	15.72	*1.078*	6182	**0.944**	16.64	*1.137*	6419	0.980
	14.42	7576	15.19	1.050	5953	**0.789**	15.40	*1.064*	6151	**0.814**
	20.52	12844	13.14	**0.657**	6298	**0.494**	12.17	**0.612**	5561	**0.437**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
tls5	64.33%	907346	52.10%	1.000	1465840	1.615	53.60%	1.000	1173223	1.293
	71.45%	1049855	63.49%	1.000	1314675	1.252	68.52%	1.000	1186494	1.130
	86.59%	744553	55.77%	1.000	1368044	1.837	52.81%	1.000	1433582	1.925
tls6	387.92%	301114	513.68%	1.000	258694	0.859	641.53%	1.000	345274	1.147
	410.14%	272273	471.94%	1.000	277438	1.019	464.29%	1.000	292869	1.076
	313.51%	394296	180.15%	1.000	296213	0.751	333.68%	1.000	401100	1.017
tls7	4106.09%	428648	4319.27%	1.000	385361	0.899	3850.91%	1.000	511316	1.193
	4645.29%	280748	3742.32%	1.000	555458	1.978	3387.57%	1.000	561463	2.000
	3624.78%	537262	3933.25%	1.000	391620	0.729	4062.34%	1.000	393695	0.733
tltr	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
topopt-cantilever_60x40_50	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
topopt-mbb_60x40_50	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
topopt-zhou-rozvany_75	10.83%	1	10.83%	1.000	1	1.000	10.83%	1.000	1	1.000
	10.83%	55	10.83%	1.000	55	1.000	10.83%	1.000	55	1.000
toroidal2g20_5555	187.89%	565	187.85%	1.000	572	1.011	187.85%	1.000	571	1.009
	187.85%	569	187.85%	1.000	573	1.006	187.85%	1.000	571	1.003
	187.85%	571	187.85%	1.000	571	1.000	187.85%	1.000	571	1.000
toroidal3g7_6666	270.98%	1138	278.97%	1.000	1142	1.003	256.65%	1.000	1157	1.015
	270.98%	1138	256.65%	1.000	1151	1.011	256.65%	1.000	1147	1.007
	270.98%	1138	256.65%	1.000	1147	1.007	278.97%	1.000	1140	1.002
transswitch0009r	345.57%	206752	345.57%	1.000	206811	1.000	345.57%	1.000	186205	0.901
	345.57%	215607	345.57%	1.000	215553	1.000	345.57%	1.000	257041	1.192
	345.57%	205488	345.57%	1.000	205570	1.000	345.57%	1.000	173440	0.844
transswitch0014r	∞	11102	∞	1.000	11088	0.999	∞	1.000	17788	1.597
	∞	33447	∞	1.000	33401	0.999	∞	1.000	46487	1.389
	∞	26728	∞	1.000	26881	1.006	∞	1.000	61082	2.281
transswitch0030r	∞	2250	∞	1.000	2250	1.000	∞	1.000	3075	1.351
	∞	1573	∞	1.000	1573	1.000	∞	1.000	3008	1.858

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	8283	∞	1.000	8288	1.001	∞	1.000	3966	0.485
transswitch0039r	∞	392	∞	1.000	392	1.000	∞	1.000	392	1.000
	∞	755	∞	1.000	757	1.002	∞	1.000	543	0.752
	∞	313	∞	1.000	313	1.000	∞	1.000	313	1.000
transswitch0057r	∞	210	∞	1.000	210	1.000	∞	1.000	210	1.000
	∞	535	∞	1.000	535	1.000	∞	1.000	536	1.002
	∞	2399	∞	1.000	2399	1.000	∞	1.000	2496	1.039
transswitch0118r	∞	10304	∞	1.000	10303	1.000	∞	1.000	10304	1.000
	∞	5166	∞	1.000	5166	1.000	∞	1.000	5165	1.000
	∞	1735	∞	1.000	1735	1.000	∞	1.000	1735	1.000
transswitch0300r	∞	80423	∞	1.000	80424	1.000	∞	1.000	80423	1.000
	∞	33136	∞	1.000	33136	1.000	∞	1.000	33136	1.000
	∞	721	∞	1.000	721	1.000	∞	1.000	721	1.000
transswitch2383wpr	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
transswitch2736spr	39.15%	1	39.15%	1.000	1	1.000	39.15%	1.000	1	1.000
	39.15%	1	39.15%	1.000	1	1.000	39.15%	1.000	1	1.000
	39.15%	1	39.15%	1.000	1	1.000	39.15%	1.000	1	1.000
tspn05	38.96	29221	22.34	**0.584**	11261	**0.387**	22.21	**0.581**	11261	**0.387**
	208.94	221561	28.80	**0.142**	16301	**0.074**	29.40	**0.145**	16301	**0.074**
	36.92	22361	13.66	**0.387**	4951	**0.225**	13.55	**0.384**	4951	**0.225**
tspn08	2.30%	634689	1.16%	1.000	583481	0.919	1.27%	1.000	588526	0.927
	3.70%	628767	3.52%	1.000	556743	0.885	3.29%	1.000	612014	0.973
	4.78%	891706	3.59%	1.000	774926	0.869	3.60%	1.000	772435	0.866
tspn10	17.88%	522485	7.39%	1.000	495630	0.949	7.17%	1.000	501662	0.960
	17.56%	551318	8.00%	1.000	534802	0.970	6.19%	1.000	515868	0.936
	18.01%	496173	7.53%	1.000	527199	1.063	6.85%	1.000	519977	1.048
tspn12	45.93%	335999	25.18%	1.000	286030	0.851	25.89%	1.000	297720	0.886
	49.35%	343488	33.02%	1.000	279310	0.813	36.04%	1.000	294037	0.856
	41.93%	304050	27.42%	1.000	230416	0.758	27.42%	1.000	230300	0.758
tspn15	22.34%	260148	21.02%	1.000	216326	0.832	22.21%	1.000	228848	0.880
	22.88%	286086	23.38%	1.000	275479	0.963	22.98%	1.000	281476	0.984
	22.72%	279089	21.85%	1.000	207696	0.744	21.02%	1.000	212715	0.762

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
unitcommit1	2.12	2	2.17	1.016	2	1.000	2.14	1.006	2	1.000
	2.32	2	2.31	0.997	2	1.000	2.32	1.000	2	1.000
	1.64	2	1.70	1.023	2	1.000	1.73	1.034	2	1.000
unitcommit2	19.52%	2434	19.51%	1.000	2442	1.003	19.51%	1.000	2446	1.005
	17.25%	2118	17.25%	1.000	2114	0.998	17.25%	1.000	2118	1.000
	16.49%	1929	16.49%	1.000	1934	1.002	16.49%	1.000	1936	1.003
unitcommit_200_100_1_mod_8	0.12%	334	0.13%	1.000	227	0.753	0.13%	1.000	227	0.753
	0.16%	28	0.16%	1.000	28	1.000	0.16%	1.000	28	1.000
	0.13%	67	0.13%	1.000	67	1.000	0.13%	1.000	67	1.000
unitcommit_200_100_2_mod_7	0.04%	5471	0.04%	1.000	4002	0.736	0.04%	1.000	4022	0.740
	0.04%	5016	0.04%	1.000	3084	0.622	0.04%	1.000	3084	0.622
unitcommit_200_100_2_mod_8	0.05%	256	0.06%	1.000	183	0.795	0.06%	1.000	183	0.795
	0.06%	704	0.05%	1.000	651	0.934	0.05%	1.000	651	0.934
	0.04%	632	0.06%	1.000	192	0.399	0.06%	1.000	192	0.399
unitcommit_50_20_2_mod_8	0.02%	48871	0.02%	1.000	45173	0.924	0.02%	1.000	45139	0.924
	0.02%	48336	0.02%	1.000	34207	0.708	0.02%	1.000	34156	0.707
	0.01%	42192	0.02%	1.000	42170	0.999	0.02%	1.000	42084	0.997
uselinear	∞	12054	∞	1.000	12300	1.020	∞	1.000	12070	1.001
	∞	7272	∞	1.000	3256	0.455	∞	1.000	3256	0.455
	∞	1303	∞	1.000	1303	1.000	∞	1.000	1303	1.000
util	0.57	37	0.59	1.013	33	0.971	0.59	1.013	33	0.971
	0.50	22	0.50	1.000	22	1.000	0.50	1.000	22	1.000
	0.50	17	0.50	1.000	17	1.000	0.50	1.000	17	1.000
waste	78.64%	2312198	78.58%	1.000	2315354	1.001	78.63%	1.000	2294128	0.992
	79.35%	2166976	80.84%	1.000	2122147	0.979	80.14%	1.000	2195967	1.013
wastepaper3	10.60	8503	10.47	0.989	8503	1.000	7.62	**0.743**	6407	**0.756**
	388.94	539080	354.85	**0.913**	512493	0.951	324.54	**0.835**	446782	**0.829**
	361.22	506259	350.62	0.971	506753	1.001	166.77	**0.463**	208495	**0.412**
wastepaper5	∞	9218549	∞	1.000	8487485	0.921	1804.33	**0.251**	1971234	**0.214**
wastepaper6	∞	6475561	∞	1.000	6475547	1.000	∞	1.000	6367951	0.983
	162.05%	2890296	147.07%	1.000	1982887	0.686	149.41%	1.000	2045076	0.708
water4	68.59%	3937338	55.29%	1.000	3854790	0.979	62.95%	1.000	3709569	0.942
	57.91%	4212386	51.07%	1.000	4104686	0.974	61.73%	1.000	3506868	0.833

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	71.36%	3517147	45.84%	1.000	4533838	1.289	63.21%	1.000	4055774	1.153
watercontamination0202	202.80	39	202.00	0.996	39	1.000	201.78	0.995	39	1.000
	86.80	34	87.01	1.002	34	1.000	87.24	1.005	34	1.000
watercontamination0202r	203.22	7	203.91	1.003	7	1.000	203.50	1.001	7	1.000
	184.93	18	184.42	0.997	18	1.000	184.09	0.995	18	1.000
	1792.86	21	1806.65	1.008	21	1.000	1795.06	1.001	21	1.000
watercontamination0303	∞	91	∞	1.000	123	1.168	∞	1.000	123	1.168
	∞	131	∞	1.000	85	0.801	∞	1.000	85	0.801
	∞	188	∞	1.000	75	0.608	∞	1.000	75	0.608
watercontamination0303r	∞	16	∞	1.000	16	1.000	∞	1.000	16	1.000
	∞	16	∞	1.000	16	1.000	∞	1.000	16	1.000
	∞	16	∞	1.000	16	1.000	∞	1.000	16	1.000
waternd1	12.99	5040	13.56	1.041	5040	1.000	31.03	*2.289*	63501	*12.374*
	12.63	8441	10.50	**0.844**	3988	**0.479**	10.39	**0.836**	3988	**0.479**
waternd2	4.27%	2824623	2.99%	1.000	2518380	0.892	3.25%	1.000	2515026	0.890
	70.19%	2237805	4.26%	1.000	2290732	1.024	2.46%	1.000	2270959	1.015
	3.22%	2549690	1.98%	1.000	1831971	0.719	1.98%	1.000	2211658	0.867
	∞	378241	∞	1.000	1794357	4.743	∞	1.000	1271193	3.360
waternd_fosspoly0	∞	1332033	∞	1.000	1529540	1.148	∞	1.000	1301481	0.977
	∞	1846435	∞	1.000	1748965	0.947	∞	1.000	1801007	0.975
waternd_hanoi	297.36	71193	290.12	0.976	71054	0.998	262.64	**0.884**	60889	**0.855**
	405.97	102387	439.55	*1.083*	104059	1.016	508.36	*1.252*	125758	*1.228*
waternd_modena	∞	283252	∞	1.000	221776	0.783	∞	1.000	233772	0.825
	∞	333389	∞	1.000	188349	0.565	∞	1.000	199429	0.598
	∞	310944	∞	1.000	168616	0.542	∞	1.000	269331	0.866
waternd_pescara	∞	394314	∞	1.000	397009	1.007	∞	1.000	373100	0.946
	∞	292334	∞	1.000	353493	1.209	∞	1.000	393144	1.345
	∞	426342	∞	1.000	430058	1.009	∞	1.000	433708	1.017
waternd_shamir	8.04	4317	7.91	0.986	3430	**0.799**	7.90	0.985	3447	**0.803**
	10.66	5541	9.91	**0.936**	5104	**0.923**	10.01	**0.944**	5108	**0.923**
	9.55	5221	6.99	**0.757**	3029	**0.588**	7.20	**0.777**	3029	**0.588**
waterno1_01	0.50	2	0.50	1.000	2	1.000	0.50	1.000	2	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	3.40	323	3.73	*1.075*	336	1.031	3.72	*1.073*	336	1.031
waterno1_03	9.40	1004	7.53	**0.820**	942	**0.944**	9.44	1.004	1172	*1.152*
	14.78	2102	9.33	**0.655**	912	**0.460**	8.28	**0.588**	762	**0.391**
	36.87	5031	35.82	0.972	3751	**0.751**	29.81	**0.814**	2841	**0.573**
waterno1_18	17.38%	106340	17.12%	1.000	101536	0.955	17.62%	1.000	91315	0.859
	13.42%	189041	18.10%	1.000	115269	0.610	15.14%	1.000	117893	0.624
	13.85%	165518	32.36%	1.000	23295	0.141	10.94%	1.000	176779	1.068
waterno1_24	19.86%	86418	17.08%	1.000	92553	1.071	15.37%	1.000	91082	1.054
	0.76	10	0.75	0.994	10	1.000	0.76	1.000	10	1.000
	0.56	14	0.57	1.006	14	1.000	0.57	1.006	14	1.000
	0.59	16	0.61	1.013	16	1.000	0.62	1.019	16	1.000
waterno2_02	2.82	332	2.76	0.984	332	1.000	2.82	1.000	332	1.000
	2.39	292	2.38	0.997	292	1.000	2.34	0.985	292	1.000
	2.45	231	2.45	1.000	231	1.000	2.45	1.000	231	1.000
waterno2_03	350.14	119416	415.79	*1.187*	166631	*1.395*	430.09	*1.228*	171150	*1.433*
	297.79	95243	317.64	*1.066*	103613	*1.088*	197.54	**0.664**	49806	**0.523**
	277.48	70395	274.08	0.988	68965	0.980	393.54	*1.417*	126959	*1.802*
waterno2_04	38.47%	516725	10.64%	1.000	636099	1.231	7.92%	1.000	572981	1.109
	53.70%	1030853	13.60%	1.000	972192	0.943	48.41%	1.000	726802	0.705
waterno2_09	851.42%	228087	851.17%	1.000	223483	0.980	784.37%	1.000	228181	1.000
	1022.77%	179647	796.89%	1.000	189121	1.053	839.63%	1.000	191896	1.068
waterno2_12	1162.18%	194790	883.13%	1.000	205113	1.053	937.18%	1.000	189168	0.971
	982.93%	167793	1116.77%	1.000	167326	0.997	1156.07%	1.000	166469	0.992
waterno2_24	3868.89%	48368	4018.60%	1.000	44959	0.930	3994.53%	1.000	44597	0.922
waters	150.31%	5126692	145.27%	1.000	4805319	0.937	146.27%	1.000	4748901	0.926
	210.76%	5082985	200.63%	1.000	4378686	0.861	189.36%	1.000	4310903	0.848
	267.13%	4740514	255.07%	1.000	5317788	1.122	261.19%	1.000	5229732	1.103
watersbp	80.90%	5393949	77.83%	1.000	6445388	1.195	100.95%	1.000	5454431	1.011
	96.79%	5750280	78.09%	1.000	6295945	1.095	90.05%	1.000	5128779	0.892
	114.93%	6374064	116.15%	1.000	3080734	0.483	92.15%	1.000	5109281	0.802
watersym1	87.75%	1441507	67.17%	1.000	930345	0.645	57.12%	1.000	1510533	1.048
	13.60	11211	15.36	*1.121*	12351	*1.101*	15.09	*1.102*	12351	*1.101*
	49.10	65951	484.12	*9.683*	415461	*6.292*	21.88	**0.457**	15041	**0.229**

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Table E.2: Detailed computational results on nonconvex instances of MinlpLib.

	nolpinf		combined				combined-local			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.69%	10124086	1.29%	1.000	8159452	0.806	1.29%	1.000	8325458	0.822
watertreatnd_flow	102.05	45948	102.39	1.003	45948	1.000	102.62	1.006	45948	1.000
	34.40	12441	34.53	1.004	12441	1.000	34.16	0.993	12441	1.000
	95.59	54988	274.37	*2.851*	170696	*3.100*	276.28	*2.871*	170696	*3.100*
waterx	11.53%	748542	12.62%	1.000	744478	0.995	15.76%	1.000	866211	1.157
	12.27%	776202	11.52%	1.000	698280	0.900	12.25%	1.000	715641	0.922
waterz	179.33%	11503462	524.99%	1.000	311582	0.027	1022.12%	1.000	103058	0.009
	1500.39%	21924	1107.79%	1.000	89679	4.076	107.59%	1.000	5950472	270.186
	1121.83%	52363	224.49%	1.000	8250171	157.259	800.78%	1.000	55123	1.053

Table E.3: Detailed computational results on nonconvex instances of MinlpLib. Relative changes by at least 5% are highlighted in bold and blue (**improvement**) or italic and red (*deterioration*).

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
4stufen	884.84%	29134	884.84%	1.000	30114	1.034	884.84%	1.000	17317	0.596
	884.84%	20959	884.84%	1.000	29349	1.398	884.84%	1.000	18542	0.885
	884.56%	13108	884.56%	1.000	13108	1.000	884.01%	1.000	17946	1.366
alan	0.53	9	0.51	0.987	9	1.000	0.54	1.007	9	1.000
	0.64	9	0.61	0.982	9	1.000	0.61	0.982	9	1.000
	8.27	11	8.28	1.001	11	1.000	8.28	1.001	11	1.000
autocorr_bern20-05	274.28%	254569	218.51%	1.000	251924	0.990	218.75%	1.000	251025	0.986
	274.28%	254642	218.51%	1.000	251317	0.987	218.27%	1.000	252008	0.990
	275.00%	252886	218.27%	1.000	252137	0.997	218.51%	1.000	251654	0.995
autocorr_bern20-10	836.51%	80870	797.07%	1.000	73185	0.905	797.07%	1.000	72600	0.898
	836.51%	80706	797.07%	1.000	73141	0.906	797.07%	1.000	72276	0.896
	836.51%	80276	797.07%	1.000	72955	0.909	797.07%	1.000	73255	0.913
autocorr_bern20-15	1171.30%	47549	1140.67%	1.000	44239	0.931	1141.48%	1.000	43945	0.924
	1172.82%	47123	1140.45%	1.000	45414	0.964	1140.78%	1.000	44850	0.952
	1170.31%	47656	1141.10%	1.000	44505	0.934	1139.47%	1.000	44678	0.938
autocorr_bern25-06	1155.62%	98699	1036.46%	1.000	101431	1.028	1036.46%	1.000	101449	1.028
	1155.62%	99204	1036.46%	1.000	101790	1.026	1036.46%	1.000	101193	1.020
	1155.62%	99331	1036.46%	1.000	101781	1.025	1036.46%	1.000	101605	1.023
autocorr_bern25-13	1625.66%	29997	1601.58%	1.000	26073	0.870	1602.90%	1.000	27334	0.912
	1627.16%	28677	1601.88%	1.000	27378	0.955	1601.88%	1.000	26717	0.932
	1627.42%	29631	1601.58%	1.000	25490	0.861	1601.70%	1.000	27373	0.924
autocorr_bern25-19	1854.46%	13635	1834.35%	1.000	12528	0.919	1834.26%	1.000	11815	0.867
	1854.86%	12715	1834.26%	1.000	10502	0.827	1834.04%	1.000	11185	0.881
	1854.46%	13303	1834.24%	1.000	12366	0.930	1834.68%	1.000	11579	0.871
autocorr_bern25-25	1942.01%	7197	1975.97%	1.000	10260	1.420	1974.02%	1.000	11249	1.555
	1941.92%	8722	1974.09%	1.000	10371	1.187	1974.11%	1.000	9241	1.059
	1941.96%	8976	1974.02%	1.000	10332	1.149	1974.11%	1.000	10189	1.134
autocorr_bern30-08	1356.91%	38358	1321.04%	1.000	37547	0.979	1320.73%	1.000	37323	0.973
	1357.83%	37679	1320.87%	1.000	37538	0.996	1320.83%	1.000	37319	0.990
	1356.64%	37578	1321.17%	1.000	36204	0.964	1321.14%	1.000	36837	0.980
autocorr_bern30-15	1900.42%	7073	1920.92%	1.000	7705	1.088	1921.11%	1.000	8281	1.168
	1900.39%	9482	1920.92%	1.000	8650	0.913	1921.11%	1.000	9088	0.959
	1900.39%	10034	1920.92%	1.000	9439	0.941	1921.11%	1.000	6923	0.693

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
autocorr_bern30-23	2104.58%	3991	2101.83%	1.000	3944	0.989	2101.82%	1.000	3955	0.991
	2104.58%	3988	2101.60%	1.000	5644	1.405	2101.69%	1.000	4922	1.228
	2104.65%	3977	2101.69%	1.000	3956	0.995	2101.67%	1.000	4766	1.194
autocorr_bern30-30	2123.47%	3209	2126.41%	1.000	2510	0.789	2126.41%	1.000	3318	1.033
	2123.39%	2506	2126.55%	1.000	3679	1.450	2126.35%	1.000	2515	1.003
	2123.30%	2476	2126.41%	1.000	2509	1.013	2126.41%	1.000	3609	1.440
autocorr_bern35-09	1617.97%	27535	1582.82%	1.000	25229	0.917	1583.02%	1.000	25285	0.919
	1617.97%	26844	1582.93%	1.000	24324	0.906	1583.18%	1.000	25307	0.943
	1617.95%	26312	1583.02%	1.000	24927	0.948	1582.93%	1.000	24774	0.942
autocorr_bern35-18	2062.19%	3965	2065.41%	1.000	5457	1.367	2065.63%	1.000	3888	0.981
	2062.22%	3959	2065.41%	1.000	3909	0.988	2065.31%	1.000	3915	0.989
	2062.19%	3961	2065.41%	1.000	4924	1.237	2065.61%	1.000	4478	1.127
autocorr_bern35-26	2181.66%	2830	2180.73%	1.000	2060	0.737	2180.76%	1.000	2054	0.735
	2181.56%	2067	2180.83%	1.000	2389	1.149	2180.76%	1.000	2053	0.994
	2181.56%	2068	2180.76%	1.000	2397	1.152	2180.76%	1.000	2953	1.408
autocorr_bern35-35fix	∞	1627	∞	1.000	1761	1.078	∞	1.000	1591	0.979
	∞	1626	∞	1.000	2865	1.718	∞	1.000	1595	0.982
	∞	1631	∞	1.000	2299	1.386	∞	1.000	1596	0.980
autocorr_bern40-05	991.03%	91115	950.00%	1.000	88242	0.969	950.11%	1.000	88601	0.972
	991.13%	91551	949.79%	1.000	88778	0.970	949.68%	1.000	88941	0.972
	991.03%	91034	950.00%	1.000	88515	0.972	949.79%	1.000	89350	0.982
autocorr_bern40-10	1803.95%	14372	1792.20%	1.000	13035	0.908	1792.20%	1.000	14747	1.026
	1803.96%	14526	1792.20%	1.000	13356	0.920	1792.09%	1.000	13358	0.920
	1803.87%	14657	1792.21%	1.000	14643	0.999	1792.09%	1.000	14210	0.970
autocorr_bern40-20	2140.37%	3405	2140.44%	1.000	2316	0.689	2140.37%	1.000	2338	0.696
	2140.37%	2324	2140.40%	1.000	2330	1.002	2140.40%	1.000	2333	1.004
	2140.37%	2328	2140.40%	1.000	2913	1.241	2140.44%	1.000	2320	0.997
autocorr_bern40-30	2254.19%	1113	2265.26%	1.000	1095	0.985	2265.26%	1.000	1094	0.984
	2254.50%	1110	2265.26%	1.000	1091	0.984	2265.34%	1.000	1091	0.984
	2254.50%	1112	2265.26%	1.000	1091	0.983	2265.26%	1.000	1092	0.983
autocorr_bern40-40	2242.28%	761	2245.54%	1.000	777	1.019	2245.54%	1.000	778	1.020
	2242.28%	763	2245.54%	1.000	778	1.017	2245.54%	1.000	778	1.017
	2242.28%	761	2245.54%	1.000	779	1.021	2245.54%	1.000	779	1.021
autocorr_bern45-05	1040.36%	76313	1003.18%	1.000	73214	0.959	1003.09%	1.000	72833	0.954

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1040.36%	75266	1003.18%	1.000	72732	0.966	1003.28%	1.000	73292	0.974
	1040.36%	75649	1003.37%	1.000	72661	0.961	1003.09%	1.000	73153	0.967
autocorr_bern45-11	1888.53%	9053	1891.07%	1.000	7803	0.863	1891.19%	1.000	9777	1.079
	1888.33%	10018	1891.70%	1.000	9118	0.911	1891.19%	1.000	9923	0.991
	1888.45%	9201	1891.25%	1.000	8134	0.885	1891.19%	1.000	9212	1.001
autocorr_bern45-23	2214.49%	1344	2219.00%	1.000	1338	0.996	2219.00%	1.000	2112	1.532
	2214.49%	1345	2218.76%	1.000	1339	0.996	2219.00%	1.000	1337	0.994
	2214.49%	1859	2219.00%	1.000	1336	0.733	2219.00%	1.000	1600	0.868
autocorr_bern45-34	2406.56%	32	2406.56%	1.000	32	1.000	2406.56%	1.000	32	1.000
	2406.56%	32	2406.56%	1.000	32	1.000	2406.56%	1.000	32	1.000
	2406.56%	32	2406.56%	1.000	32	1.000	2406.56%	1.000	32	1.000
autocorr_bern45-45	2297.42%	375	2297.42%	1.000	596	1.465	2297.42%	1.000	376	1.002
	2297.42%	375	2297.42%	1.000	375	1.000	2297.42%	1.000	376	1.002
	2297.42%	376	2297.42%	1.000	377	1.002	2297.42%	1.000	376	1.000
autocorr_bern50-06	1438.10%	39861	1429.25%	1.000	39224	0.984	1429.25%	1.000	38861	0.975
	1438.15%	39494	1429.80%	1.000	38596	0.977	1429.82%	1.000	39418	0.998
	1438.13%	40486	1429.27%	1.000	38942	0.962	1429.37%	1.000	38295	0.946
autocorr_bern50-13	1981.35%	5034	1984.83%	1.000	5512	1.093	1984.85%	1.000	4526	0.901
	1981.33%	3742	1984.86%	1.000	5685	1.506	1984.85%	1.000	3816	1.019
	1981.45%	3734	1984.85%	1.000	3777	1.011	1984.86%	1.000	5020	1.335
autocorr_bern50-25	2255.50%	816	2266.26%	1.000	820	1.004	2266.26%	1.000	817	1.001
	2255.50%	809	2266.44%	1.000	815	1.007	2266.44%	1.000	813	1.004
	2255.50%	818	2266.44%	1.000	814	0.996	2266.26%	1.000	816	0.998
autocorr_bern50-38	2437.34%	1	2437.34%	1.000	1	1.000	2437.34%	1.000	1	1.000
	2437.34%	1	2437.34%	1.000	1	1.000	2437.34%	1.000	1	1.000
	2437.34%	1	2437.34%	1.000	1	1.000	2437.34%	1.000	1	1.000
autocorr_bern50-50	2387.30%	1	2387.30%	1.000	1	1.000	2387.30%	1.000	1	1.000
	2387.30%	1	2387.30%	1.000	1	1.000	2387.30%	1.000	1	1.000
	2387.30%	1	2387.30%	1.000	1	1.000	2387.30%	1.000	1	1.000
autocorr_bern55-06	1467.22%	36013	1449.29%	1.000	35805	0.994	1449.38%	1.000	34393	0.955
	1467.20%	36199	1449.33%	1.000	34755	0.960	1449.44%	1.000	34506	0.953
	1467.26%	35410	1449.44%	1.000	34933	0.987	1449.33%	1.000	34958	0.987
autocorr_bern55-14	2049.71%	4412	2048.51%	1.000	2985	0.684	2048.51%	1.000	2978	0.682
	2049.71%	3738	2048.51%	1.000	3919	1.047	2048.51%	1.000	3609	0.966

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	2049.71%	2979	2048.51%	1.000	3755	1.252	2048.51%	1.000	2989	1.003
autocorr_bern55-28	2309.67%	386	2309.63%	1.000	387	1.002	2309.63%	1.000	385	0.998
	2309.67%	840	2309.63%	1.000	386	0.517	2309.63%	1.000	387	0.518
	2309.67%	386	2309.63%	1.000	385	0.998	2309.63%	1.000	384	0.996
autocorr_bern55-41	3657.92%	2	3657.92%	1.000	2	1.000	3657.92%	1.000	2	1.000
	3657.92%	2	3657.92%	1.000	2	1.000	3657.92%	1.000	2	1.000
	3657.92%	2	3657.92%	1.000	2	1.000	3657.92%	1.000	2	1.000
autocorr_bern55-55	3579.32%	2	3579.32%	1.000	2	1.000	3579.32%	1.000	2	1.000
	3579.32%	2	3579.32%	1.000	2	1.000	3579.32%	1.000	2	1.000
	3579.32%	2	3579.32%	1.000	2	1.000	3579.32%	1.000	2	1.000
autocorr_bern60-08	1716.74%	12547	1714.13%	1.000	11911	0.950	1714.06%	1.000	12893	1.027
	1716.84%	12911	1714.15%	1.000	12139	0.941	1714.38%	1.000	12138	0.941
	1716.91%	12434	1714.15%	1.000	13143	1.057	1714.15%	1.000	13519	1.087
autocorr_bern60-15	2098.92%	2249	2097.56%	1.000	2249	1.000	2097.55%	1.000	3358	1.472
	2098.92%	2250	2097.58%	1.000	2242	0.997	2097.56%	1.000	3475	1.521
	2098.92%	2239	2097.56%	1.000	2247	1.003	2097.56%	1.000	2248	1.004
autocorr_bern60-30	2342.70%	115	2342.70%	1.000	115	1.000	2342.70%	1.000	115	1.000
	2343.40%	115	2343.40%	1.000	115	1.000	2342.70%	1.000	115	1.000
	2342.70%	115	2342.70%	1.000	115	1.000	2342.70%	1.000	115	1.000
ball_mk2_10	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ball_mk2_30	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ball_mk4_05	23.87	1917	24.07	1.008	1917	1.000	24.20	1.013	1917	1.000
	24.05	1917	24.27	1.009	1917	1.000	24.04	1.000	1917	1.000
	24.15	1917	24.31	1.006	1917	1.000	23.97	0.993	1917	1.000
ball_mk4_10	∞	554517	∞	1.000	555279	1.001	∞	1.000	549957	0.992
	∞	554341	∞	1.000	552579	0.997	∞	1.000	553260	0.998
	∞	551829	∞	1.000	550468	0.998	∞	1.000	552249	1.001
ball_mk4_15	∞	559526	∞	1.000	556735	0.995	∞	1.000	555988	0.994
	∞	557488	∞	1.000	556074	0.997	∞	1.000	555569	0.997
	∞	558443	∞	1.000	554735	0.993	∞	1.000	555926	0.995

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
batch0812	0.00%	3232	0.00%	1.000	11455	3.468	0.00%	1.000	4090	1.258
	0.00%	14427	0.00%	1.000	3372	0.239	5185.59	**0.720**	2634	**0.188**
	0.00%	3309	0.00%	1.000	3311	1.001	0.00%	1.000	4269	1.282
batch0812_nc	9.20%	24628	9.20%	1.000	26990	1.096	9.20%	1.000	28104	1.141
	9.20%	33621	9.20%	1.000	31581	0.940	9.20%	1.000	33329	0.991
	9.20%	32286	9.20%	1.000	25517	0.791	9.20%	1.000	33278	1.031
batch	1092.29	930	1096.23	1.004	930	1.000	51.09	**0.048**	253	**0.343**
	1344.58	1033	1349.80	1.004	1033	1.000	46.73	**0.035**	253	**0.312**
	862.07	852	860.39	0.998	852	1.000	295.99	**0.344**	141	**0.253**
batch_nc	92.90%	79982	92.90%	1.000	78683	0.984	92.90%	1.000	68186	0.853
	59.55%	75916	59.55%	1.000	76986	1.014	59.55%	1.000	75177	0.990
	45.43%	57517	45.43%	1.000	57523	1.000	45.43%	1.000	57517	1.000
batchdes	48.01	201	48.08	1.001	201	1.000	0.56	**0.032**	13	**0.375**
	200.87	271	200.77	1.000	271	1.000	62.35	**0.314**	206	**0.825**
	196.75	271	194.74	0.990	271	1.000	120.77	**0.616**	285	1.038
batchs101006m	4261.40	15221	4230.04	0.993	15221	1.000	2948.39	**0.692**	11773	**0.775**
	4553.86	14639	4569.55	1.003	14639	1.000	3065.80	**0.673**	12337	**0.844**
	3573.33	12559	3560.64	0.996	12559	1.000	3426.46	0.959	14627	*1.163*
batchs121208m	0.92%	22348	0.92%	1.000	22540	1.009	0.72%	1.000	19753	0.884
	0.97%	26521	0.97%	1.000	20061	0.757	0.71%	1.000	18595	0.702
	0.97%	26605	0.97%	1.000	22299	0.839	0.83%	1.000	19652	0.740
batchs151208m	1.29%	20493	1.29%	1.000	18572	0.907	1.08%	1.000	17649	0.862
	1.23%	21626	1.23%	1.000	19079	0.883	1.13%	1.000	17220	0.797
	1.29%	22466	1.29%	1.000	16303	0.727	1.14%	1.000	16543	0.738
batchs201210m	0.84%	17681	0.84%	1.000	19031	1.076	0.75%	1.000	13269	0.752
	0.84%	13771	0.84%	1.000	14013	1.017	0.78%	1.000	11751	0.854
	0.84%	11101	0.84%	1.000	10880	0.980	0.80%	1.000	11583	1.043
bchoco05	5.05%	16605	5.05%	1.000	17452	1.051	5.05%	1.000	12981	0.783
	5.05%	18299	5.05%	1.000	18721	1.023	5.05%	1.000	12424	0.681
	5.05%	18738	5.05%	1.000	18887	1.008	5.05%	1.000	13741	0.735
bchoco06	3.86%	9973	3.86%	1.000	10508	1.053	3.86%	1.000	10419	1.044
	3.86%	11013	3.86%	1.000	10174	0.925	3.86%	1.000	9474	0.862
	3.86%	9529	3.86%	1.000	10883	1.141	3.86%	1.000	9829	1.031
bchoco07	3.84%	4852	3.84%	1.000	3767	0.781	3.84%	1.000	6505	1.334

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	3.84%	6199	3.84%	1.000	5484	0.886	3.84%	1.000	6071	0.980
	3.84%	3832	3.84%	1.000	6683	1.725	3.84%	1.000	6346	1.639
bchoco08	3.18%	4202	3.18%	1.000	3225	0.773	3.18%	1.000	5656	1.338
	3.18%	2393	3.18%	1.000	4860	1.990	3.18%	1.000	5579	2.278
	3.18%	2455	3.18%	1.000	2455	1.000	3.18%	1.000	2455	1.000
beuster	1855.95%	42181	1855.95%	1.000	42719	1.013	1855.95%	1.000	40767	0.967
	1855.95%	38041	1855.95%	1.000	39436	1.037	1855.95%	1.000	36474	0.959
	1855.95%	40876	1855.95%	1.000	39339	0.962	1855.95%	1.000	38726	0.948
blend029	31.80%	111877	31.80%	1.000	109560	0.979	31.80%	1.000	111110	0.993
	31.80%	110257	31.80%	1.000	106413	0.965	31.80%	1.000	100475	0.911
	31.80%	107838	31.80%	1.000	110636	1.026	31.80%	1.000	109004	1.011
blend146	6.18%	69044	6.18%	1.000	69189	1.002	6.18%	1.000	63631	0.922
	6.18%	63244	6.18%	1.000	68807	1.088	6.18%	1.000	70861	1.120
	6.18%	70558	6.18%	1.000	64458	0.914	6.18%	1.000	70931	1.005
blend480	19.54%	53108	19.37%	1.000	55102	1.037	19.37%	1.000	55213	1.040
	20.37%	49888	20.14%	1.000	52715	1.057	20.14%	1.000	51736	1.037
	20.57%	50447	20.57%	1.000	53587	1.062	20.57%	1.000	53765	1.066
blend531	6.83%	67836	6.83%	1.000	68216	1.006	6.83%	1.000	67729	0.998
	6.83%	69111	6.80%	1.000	67678	0.979	6.80%	1.000	68168	0.986
	6.83%	68466	6.83%	1.000	67455	0.985	6.83%	1.000	66571	0.972
blend718	176.11%	109751	176.17%	1.000	111637	1.017	176.17%	1.000	110984	1.011
	176.07%	110279	176.07%	1.000	110792	1.005	176.07%	1.000	110625	1.003
	175.93%	110031	176.08%	1.000	109888	0.999	176.08%	1.000	110990	1.009
blend721	4.66%	64286	4.67%	1.000	63322	0.985	4.68%	1.000	63002	0.980
	4.65%	64089	4.66%	1.000	63196	0.986	4.66%	1.000	61105	0.954
	4.69%	63483	4.69%	1.000	61888	0.975	4.69%	1.000	62427	0.983
blend852	1.95%	48509	1.95%	1.000	47175	0.973	1.95%	1.000	48692	1.004
	1.99%	49066	1.99%	1.000	48456	0.988	1.99%	1.000	42851	0.874
	1.94%	47489	1.94%	1.000	48078	1.012	1.94%	1.000	49890	1.050
cardqp_inlp	1436.71%	446	1436.71%	1.000	414	0.941	1436.71%	1.000	405	0.925
	1436.71%	536	1436.71%	1.000	560	1.038	1436.71%	1.000	538	1.003
	1436.71%	476	1436.71%	1.000	498	1.038	1436.71%	1.000	512	1.062
cardqp_iqp	1436.71%	468	1436.71%	1.000	421	0.917	1436.71%	1.000	404	0.887
	1436.71%	484	1436.71%	1.000	510	1.045	1436.71%	1.000	510	1.045

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1436.71%	522	1436.71%	1.000	447	0.879	1436.71%	1.000	480	0.932
carton7	379.32%	116765	379.32%	1.000	119908	1.027	379.32%	1.000	118707	1.017
	430.94%	107303	379.32%	1.000	117269	1.093	379.32%	1.000	117737	1.097
	439.24%	109065	379.32%	1.000	119468	1.095	379.32%	1.000	118441	1.086
carton9	412.84%	78227	373.39%	1.000	78985	1.010	405.82%	1.000	88606	1.133
	412.84%	75899	362.72%	1.000	79312	1.045	405.82%	1.000	87423	1.152
	412.84%	76438	362.72%	1.000	78877	1.032	412.84%	1.000	87679	1.147
casctanks	239.11%	14955	239.11%	1.000	15990	1.069	239.11%	1.000	10407	0.698
	239.11%	13050	239.11%	1.000	12456	0.955	239.11%	1.000	12396	0.950
	239.11%	12180	239.11%	1.000	15051	1.234	239.11%	1.000	10826	0.890
case_1scv2	$\geq$ 10000%	40	$\geq$ 10000%	1.000	40	1.000	$\geq$ 10000%	1.000	40	1.000
	$\geq$ 10000%	82	$\geq$ 10000%	1.000	82	1.000	$\geq$ 10000%	1.000	82	1.000
	$\geq$ 10000%	65	$\geq$ 10000%	1.000	65	1.000	$\geq$ 10000%	1.000	65	1.000
cecil_13	251.86%	9073	251.86%	1.000	10906	1.200	251.86%	1.000	13480	1.480
	251.86%	10721	251.86%	1.000	11825	1.102	251.86%	1.000	12171	1.134
	251.86%	10102	251.86%	1.000	10447	1.034	251.86%	1.000	12097	1.196
celar6-sub0	∞	262192	∞	1.000	261293	0.997	∞	1.000	260949	0.995
	∞	262334	∞	1.000	262014	0.999	∞	1.000	261810	0.998
	∞	261571	∞	1.000	261317	0.999	∞	1.000	262020	1.002
chp_partload	15.57%	3705	15.57%	1.000	4213	1.134	15.57%	1.000	3701	0.999
	15.57%	3898	15.57%	1.000	3225	0.832	15.57%	1.000	3327	0.857
	15.57%	3742	15.57%	1.000	3970	1.059	15.57%	1.000	3545	0.949
chp_shorttermplan1a	∞	9014	∞	1.000	11036	1.222	∞	1.000	8247	0.916
	∞	7025	∞	1.000	9293	1.318	∞	1.000	7358	1.047
	∞	7806	∞	1.000	6957	0.893	∞	1.000	10254	1.310
chp_shorttermplan1b	∞	3410	∞	1.000	3411	1.000	∞	1.000	3905	1.141
	∞	3469	∞	1.000	5429	1.549	∞	1.000	3330	0.961
	∞	4881	∞	1.000	3518	0.726	∞	1.000	5217	1.067
chp_shorttermplan2a	∞	1686	∞	1.000	1686	1.000	∞	1.000	1821	1.076
	∞	1787	∞	1.000	1787	1.000	∞	1.000	1748	0.979
	∞	3131	∞	1.000	2707	0.869	∞	1.000	1841	0.601
chp_shorttermplan2b	∞	1413	∞	1.000	3709	2.518	∞	1.000	2914	1.992
	∞	2407	∞	1.000	1327	0.569	∞	1.000	3364	1.382
	∞	1317	∞	1.000	2884	2.106	∞	1.000	1452	1.095

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
chp_shorttermplan2c	∞	1193	∞	1.000	1193	1.000	∞	1.000	1322	1.100
	∞	889	∞	1.000	889	1.000	∞	1.000	1222	1.337
	∞	725	∞	1.000	725	1.000	∞	1.000	1012	1.348
chp_shorttermplan2d	∞	448	∞	1.000	448	1.000	∞	1.000	588	1.255
	∞	359	∞	1.000	355	0.991	∞	1.000	505	1.318
	∞	561	∞	1.000	560	0.998	∞	1.000	616	1.083
clay0203h	325.85	827	326.90	1.003	827	1.000	348.34	*1.069*	875	*1.052*
	263.06	755	262.93	1.000	755	1.000	263.66	1.002	755	1.000
	282.32	741	281.86	0.998	741	1.000	279.77	0.991	741	1.000
clay0203m	29.68	451	29.67	1.000	451	1.000	5.05	**0.197**	197	**0.539**
	25.75	435	25.67	0.997	435	1.000	3.61	**0.172**	153	**0.473**
	20.15	377	20.26	1.005	377	1.000	4.13	**0.243**	175	**0.577**
clay0204h	3693.87	9015	3794.43	1.027	9352	1.037	3916.11	*1.060*	9613	*1.066*
	3648.73	9519	3812.77	1.045	9917	1.041	3992.66	*1.094*	10271	*1.078*
	3887.77	9333	3803.52	0.978	9415	1.009	3603.46	**0.927**	8542	**0.916**
clay0204m	253.82	2643	257.11	1.013	2643	1.000	255.70	1.007	2643	1.000
	272.48	2777	273.42	1.003	2777	1.000	275.39	1.011	2777	1.000
	257.33	2657	257.78	1.002	2657	1.000	256.74	0.998	2657	1.000
clay0205h	98.10%	15932	97.26%	1.000	17521	1.099	98.10%	1.000	16380	1.028
	105.39%	19149	101.06%	1.000	17088	0.893	99.81%	1.000	15727	0.822
	96.54%	20577	94.41%	1.000	18590	0.904	100.56%	1.000	15937	0.776
clay0205m	3810.15	44727	3781.40	0.992	44300	0.990	3453.41	**0.906**	40334	**0.902**
	3993.16	46643	3869.35	0.969	46076	0.988	3589.30	**0.899**	43419	**0.931**
	3707.88	44001	3953.65	*1.066*	46427	*1.055*	3695.19	0.997	45227	1.028
clay0303h	1580.69	2669	1504.85	0.952	2666	0.999	1505.35	0.952	2666	0.999
	1535.78	2653	1540.63	1.003	2653	1.000	1537.65	1.001	2653	1.000
	1528.34	2685	1517.74	0.993	2685	1.000	1514.72	0.991	2685	1.000
clay0303m	32.67	451	32.74	1.002	451	1.000	20.20	**0.630**	311	**0.746**
	28.97	451	28.99	1.001	451	1.000	11.45	**0.415**	285	**0.699**
	28.49	439	28.56	1.002	439	1.000	27.66	0.972	311	**0.763**
clay0304h	949.87%	26455	941.72%	1.000	23230	0.879	941.72%	1.000	24806	0.938
	940.37%	23762	937.69%	1.000	25543	1.075	937.69%	1.000	19136	0.806
	994.09%	26366	973.66%	1.000	26500	1.005	973.66%	1.000	26185	0.993
clay0304m	179.62	4679	173.50	0.966	4607	0.985	143.40	**0.799**	4233	**0.907**

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	200.67	4771	200.05	0.997	4685	0.982	164.19	**0.819**	4429	**0.930**
	151.10	4467	151.32	1.001	4517	1.011	139.75	**0.925**	4221	**0.946**
clay0305h	233.02%	18169	233.02%	1.000	17013	0.937	233.02%	1.000	14716	0.811
	246.95%	17182	230.98%	1.000	18203	1.059	230.98%	1.000	15337	0.893
	254.16%	19315	241.46%	1.000	16385	0.849	246.95%	1.000	14230	0.738
clay0305m	5141.15	54269	5172.12	1.006	53636	0.988	4710.81	**0.916**	50476	**0.930**
	4990.04	53479	5111.61	1.024	53663	1.003	4733.79	**0.949**	51945	0.971
	5109.05	54143	4969.03	0.973	52297	0.966	4509.56	**0.883**	48908	**0.903**
color_lab6b_4x20	∞	91764	∞	1.000	91463	0.997	∞	1.000	91204	0.994
	∞	91815	∞	1.000	91499	0.997	∞	1.000	91740	0.999
	∞	91932	∞	1.000	91470	0.995	∞	1.000	91361	0.994
contvar	745.74%	419	745.74%	1.000	419	1.000	745.74%	1.000	370	0.906
	117.23%	473	117.23%	1.000	473	1.000	117.23%	1.000	440	0.942
	745.74%	407	745.74%	1.000	408	1.002	745.74%	1.000	376	0.939
crossdock_15x7	∞	462867	∞	1.000	464311	1.003	∞	1.000	464345	1.003
	∞	467206	∞	1.000	465843	0.997	∞	1.000	466998	1.000
	∞	464726	∞	1.000	466776	1.004	∞	1.000	465056	1.001
crossdock_15x8	∞	269894	∞	1.000	271355	1.005	∞	1.000	271601	1.006
	∞	263560	∞	1.000	266247	1.010	∞	1.000	265407	1.007
	∞	271752	∞	1.000	260232	0.958	∞	1.000	259780	0.956
crudeoil_lee1_05	20.29	179	23.81	*1.165*	149	**0.892**	23.89	*1.169*	149	**0.892**
	18.19	121	16.18	**0.895**	111	0.955	16.20	**0.896**	111	0.955
	33.76	185	42.15	*1.241*	206	*1.074*	42.24	*1.244*	206	*1.074*
crudeoil_lee1_06	108.60	435	138.64	*1.274*	598	*1.305*	138.57	*1.273*	598	*1.305*
	124.74	443	265.47	*2.119*	625	*1.335*	265.48	*2.119*	625	*1.335*
	86.74	383	87.83	1.012	423	*1.083*	88.03	1.015	423	*1.083*
crudeoil_lee1_07	344.21	1105	237.16	**0.690**	678	**0.646**	237.12	**0.690**	678	**0.646**
	341.26	853	257.63	**0.756**	707	**0.847**	257.34	**0.755**	707	**0.847**
	356.87	977	180.52	**0.507**	603	**0.653**	180.14	**0.506**	603	**0.653**
crudeoil_lee1_08	669.52	1777	465.73	**0.696**	1175	**0.679**	465.49	**0.696**	1175	**0.679**
	655.74	1533	898.32	*1.369*	1482	0.969	900.93	*1.373*	1482	0.969
	708.94	1877	724.86	1.022	1426	**0.772**	724.90	1.022	1426	**0.772**
crudeoil_lee1_09	870.66	1527	607.33	**0.698**	1049	**0.706**	608.07	**0.699**	1049	**0.706**
	1030.18	1945	833.74	**0.809**	1345	**0.707**	834.05	**0.810**	1345	**0.707**

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Table E.3: Detailed computational results on nonconvex instances of MINLPLIB.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1006.29	1935	703.83	**0.700**	1187	**0.632**	704.46	**0.700**	1187	**0.632**
crudeoil_lee1_10	1628.61	1995	1019.05	**0.626**	1442	**0.736**	1019.22	**0.626**	1442	**0.736**
	0.31%	3631	1340.61	**0.186**	1452	**0.416**	1340.49	**0.186**	1452	**0.416**
	1366.70	1639	1513.35	*1.107*	1112	**0.697**	1513.70	*1.107*	1112	**0.697**
crudeoil_lee2_05	720.13	1673	714.83	0.993	1258	**0.766**	714.80	0.993	1258	**0.766**
	610.53	1685	923.27	*1.511*	1347	**0.811**	922.85	*1.511*	1347	**0.811**
	1144.97	1939	350.44	**0.307**	733	**0.409**	350.77	**0.307**	733	**0.409**
crudeoil_lee2_06	5907.43	4913	4536.59	**0.768**	3862	**0.790**	4540.67	**0.769**	3862	**0.790**
	2152.96	2993	0.56%	3.343	17921	5.826	0.56%	3.343	18050	5.868
	0.51%	6478	1.16%	1.000	5162	0.800	1.16%	1.000	5162	0.800
crudeoil_lee2_07	1.61%	17791	1.48%	1.000	8415	0.476	1.54%	1.000	5179	0.295
	1.71%	10044	1.61%	1.000	5692	0.571	1.61%	1.000	5692	0.571
	1.58%	6821	1.80%	1.000	3970	0.588	1.80%	1.000	3970	0.588
crudeoil_lee2_08	1.61%	12601	1.80%	1.000	6975	0.557	1.66%	1.000	8706	0.693
	1.80%	6303	1.80%	1.000	6950	1.101	1.80%	1.000	6260	0.993
	1.80%	6427	1.80%	1.000	5532	0.863	1.80%	1.000	6057	0.943
crudeoil_lee2_09	1.80%	4540	1.80%	1.000	4728	1.041	1.80%	1.000	4728	1.041
	1.80%	5171	1.80%	1.000	4990	0.966	1.80%	1.000	4486	0.870
	1.80%	5598	1.80%	1.000	4859	0.870	1.80%	1.000	4857	0.870
crudeoil_lee2_10	1.80%	3462	1.80%	1.000	3442	0.994	1.80%	1.000	3442	0.994
	1.80%	3190	1.80%	1.000	3909	1.219	1.80%	1.000	4562	1.417
	1.80%	3099	1.80%	1.000	3283	1.058	1.80%	1.000	3283	1.058
crudeoil_lee3_05	10.59%	10433	3.84%	1.000	7362	0.708	3.84%	1.000	6698	0.645
	11.40%	7393	7.53%	1.000	8621	1.164	7.53%	1.000	5955	0.808
	11.40%	5930	10.20%	1.000	5584	0.943	10.20%	1.000	5584	0.943
crudeoil_lee3_06	17.03%	7439	14.88%	1.000	6063	0.817	14.88%	1.000	6061	0.817
	15.16%	7623	15.31%	1.000	6135	0.807	15.31%	1.000	6132	0.807
	15.88%	7154	17.03%	1.000	6156	0.862	17.03%	1.000	8914	1.243
crudeoil_lee3_07	17.03%	7049	17.03%	1.000	6824	0.969	17.03%	1.000	12133	1.711
	17.03%	5591	17.03%	1.000	8591	1.527	17.03%	1.000	5824	1.041
	17.03%	7390	17.03%	1.000	9034	1.219	17.03%	1.000	9100	1.228
crudeoil_lee3_08	17.03%	4701	17.03%	1.000	5013	1.065	17.03%	1.000	5985	1.267
	17.03%	4542	17.03%	1.000	5776	1.266	17.03%	1.000	4238	0.935
	17.03%	4426	17.03%	1.000	4068	0.921	17.03%	1.000	4068	0.921

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
crudeoil_lee3_09	17.03%	3417	17.03%	1.000	3137	0.920	17.03%	1.000	3150	0.924
	17.03%	3568	17.03%	1.000	3120	0.878	17.03%	1.000	3119	0.878
	17.03%	3425	17.03%	1.000	3173	0.929	17.03%	1.000	3173	0.929
crudeoil_lee3_10	17.03%	2827	17.03%	1.000	2894	1.023	17.03%	1.000	2894	1.023
	17.03%	3759	17.03%	1.000	3689	0.982	17.03%	1.000	2737	0.735
	17.03%	2620	17.03%	1.000	2989	1.136	17.03%	1.000	3705	1.399
crudeoil_lee4_05	1364.69	2748	629.66	**0.462**	1154	**0.440**	630.12	**0.462**	1154	**0.440**
	1484.89	3604	769.02	**0.518**	1388	**0.402**	769.65	**0.519**	1388	**0.402**
	1394.42	2812	1091.69	**0.783**	2139	**0.769**	1092.93	**0.784**	2139	**0.769**
crudeoil_lee4_06	0.03%	13851	3964.89	**0.551**	4700	**0.344**	3968.29	**0.551**	4700	**0.344**
	6316.94	10325	2445.42	**0.387**	4263	**0.419**	2449.32	**0.388**	4263	**0.419**
	6204.59	10035	3187.90	**0.514**	4841	**0.488**	3184.81	**0.513**	4841	**0.488**
crudeoil_lee4_07	0.03%	10414	0.03%	1.000	8135	0.783	0.03%	1.000	8139	0.784
	0.03%	10118	0.03%	1.000	8025	0.795	0.03%	1.000	8024	0.795
	0.03%	10904	0.03%	1.000	6737	0.621	0.03%	1.000	6737	0.621
crudeoil_lee4_08	0.03%	8269	0.03%	1.000	6742	0.818	0.03%	1.000	6742	0.818
	0.03%	7466	0.03%	1.000	7866	1.053	0.03%	1.000	6808	0.913
	0.03%	9630	0.03%	1.000	6731	0.702	0.03%	1.000	8156	0.849
crudeoil_lee4_09	0.03%	5753	0.03%	1.000	4864	0.848	0.03%	1.000	5055	0.881
	0.03%	5290	0.03%	1.000	4939	0.935	0.03%	1.000	4939	0.935
	0.03%	5602	0.03%	1.000	4919	0.880	0.03%	1.000	4729	0.847
crudeoil_lee4_10	0.03%	3882	0.03%	1.000	3643	0.940	0.03%	1.000	3643	0.940
	0.03%	3535	0.03%	1.000	3493	0.988	0.03%	1.000	3850	1.087
	0.03%	3633	0.03%	1.000	3613	0.995	0.03%	1.000	3605	0.992
crudeoil_li01	2.40%	23270	2.40%	1.000	27092	1.164	2.40%	1.000	26138	1.123
	2.38%	26967	2.38%	1.000	26751	0.992	2.38%	1.000	26700	0.990
	2.37%	23017	2.37%	1.000	26610	1.155	2.37%	1.000	26802	1.164
crudeoil_li02	961.59%	988	961.59%	1.000	5840	5.460	961.59%	1.000	1079	1.084
	961.59%	923	961.59%	1.000	957	1.033	961.59%	1.000	957	1.033
	961.59%	878	961.59%	1.000	879	1.001	961.59%	1.000	879	1.001
crudeoil_li03	2.86%	954	2.86%	1.000	954	1.000	2.86%	1.000	954	1.000
	2.86%	2272	2.86%	1.000	4933	2.122	2.86%	1.000	2023	0.895
	2.86%	1767	2.86%	1.000	1788	1.011	2.86%	1.000	1884	1.063
crudeoil_li05	11.61%	11847	11.61%	1.000	11058	0.934	11.61%	1.000	9510	0.804

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	11.61%	11983	11.61%	1.000	12530	1.045	11.61%	1.000	11615	0.970
	11.54%	10130	11.54%	1.000	11192	1.104	11.54%	1.000	8988	0.888
crudeoil_li06	0.60%	10123	0.60%	1.000	10882	1.074	0.60%	1.000	11075	1.093
	0.60%	11659	0.60%	1.000	13203	1.131	0.60%	1.000	13325	1.142
	0.60%	12654	0.60%	1.000	12905	1.020	0.60%	1.000	11869	0.938
crudeoil_li11	2.53%	635	2.53%	1.000	635	1.000	2.53%	1.000	729	1.128
	2.53%	212	2.53%	1.000	218	1.019	2.53%	1.000	2312	7.731
	2.53%	524	2.53%	1.000	524	1.000	2.53%	1.000	524	1.000
crudeoil_li21	3.41%	543	3.41%	1.000	543	1.000	3.41%	1.000	543	1.000
	3.41%	622	3.41%	1.000	855	1.323	3.41%	1.000	2361	3.409
	3.41%	316	3.41%	1.000	316	1.000	3.41%	1.000	316	1.000
crudeoil_pooling_ct1	∞	26067	∞	1.000	19210	0.738	∞	1.000	18919	0.727
	∞	27932	∞	1.000	27672	0.991	∞	1.000	27486	0.984
	∞	28182	∞	1.000	24335	0.864	∞	1.000	24794	0.880
crudeoil_pooling_ct2	∞	28777	∞	1.000	29443	1.023	∞	1.000	29441	1.023
	∞	29353	∞	1.000	36343	1.237	∞	1.000	41413	1.409
	∞	28241	∞	1.000	23285	0.825	∞	1.000	23285	0.825
crudeoil_pooling_ct3	∞	24882	∞	1.000	17209	0.693	∞	1.000	15531	0.626
	∞	15035	∞	1.000	16336	1.086	∞	1.000	22110	1.467
	∞	7165	∞	1.000	14768	2.047	∞	1.000	13919	1.930
crudeoil_pooling_ct4	∞	39299	∞	1.000	40531	1.031	∞	1.000	45893	1.167
	∞	32757	∞	1.000	37964	1.158	∞	1.000	33140	1.012
	∞	37282	∞	1.000	41801	1.121	∞	1.000	40437	1.084
crudeoil_pooling_dt1	∞	2107	∞	1.000	2525	1.189	∞	1.000	3868	1.798
	∞	2232	∞	1.000	5168	2.259	∞	1.000	3579	1.578
	∞	2232	∞	1.000	2242	1.004	∞	1.000	2233	1.000
crudeoil_pooling_dt2	∞	2585	∞	1.000	1271	0.511	∞	1.000	1271	0.511
	∞	1214	∞	1.000	2067	1.649	∞	1.000	1120	0.928
	∞	1631	∞	1.000	1525	0.939	∞	1.000	1523	0.938
crudeoil_pooling_dt3	∞	797	∞	1.000	796	0.999	∞	1.000	797	1.000
	∞	710	∞	1.000	709	0.999	∞	1.000	708	0.998
	∞	711	∞	1.000	711	1.000	∞	1.000	713	1.002
crudeoil_pooling_dt4	∞	525	∞	1.000	1093	1.909	∞	1.000	1093	1.909
	∞	343	∞	1.000	1025	2.540	∞	1.000	1025	2.540

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	672	∞	1.000	839	1.216	∞	1.000	839	1.216
csched1	569.06%	644	569.61%	1.000	604	0.946	569.50%	1.000	615	0.961
	1451.78%	92	1451.78%	1.000	92	1.000	1451.78%	1.000	92	1.000
	572.31%	702	571.83%	1.000	722	1.025	571.67%	1.000	725	1.029
csched1a	76.42%	76	76.42%	1.000	77	1.006	76.42%	1.000	81	1.028
	76.44%	92	76.44%	1.000	85	0.964	76.44%	1.000	86	0.969
	76.46%	114	76.46%	1.000	117	1.014	76.46%	1.000	122	1.037
csched2	≥ 10000%	39587	≥ 10000%	1.000	40821	1.031	≥ 10000%	1.000	38262	0.967
	≥ 10000%	39814	≥ 10000%	1.000	39277	0.987	≥ 10000%	1.000	37724	0.948
	≥ 10000%	40112	≥ 10000%	1.000	38641	0.963	≥ 10000%	1.000	34713	0.866
csched2a	≥ 10000%	68566	≥ 10000%	1.000	69787	1.018	≥ 10000%	1.000	68578	1.000
	≥ 10000%	35233	≥ 10000%	1.000	29549	0.839	≥ 10000%	1.000	29972	0.851
	≥ 10000%	39997	≥ 10000%	1.000	39980	1.000	≥ 10000%	1.000	52097	1.302
cvxnonsep_normcon20	14.47	85	14.51	1.003	85	1.000	2.17	**0.205**	48	**0.800**
	14.50	85	14.49	0.999	85	1.000	2.23	**0.208**	48	**0.800**
	14.52	85	14.51	0.999	85	1.000	2.18	**0.205**	48	**0.800**
cvxnonsep_normcon20r	9.80	81	9.74	0.994	81	1.000	1.80	**0.259**	63	**0.901**
	21.91	83	21.95	1.002	83	1.000	2.05	**0.133**	63	**0.891**
	10.63	81	10.58	0.996	81	1.000	2.66	**0.315**	63	**0.901**
cvxnonsep_normcon30	114.24	691	114.44	1.002	691	1.000	18.18	**0.166**	640	**0.936**
	114.86	691	114.38	0.996	691	1.000	18.37	**0.167**	640	**0.936**
	114.79	691	114.18	0.995	691	1.000	18.18	**0.166**	640	**0.936**
cvxnonsep_normcon30r	89.11	634	89.35	1.003	634	1.000	18.34	**0.215**	685	*1.069*
	74.07	631	74.32	1.003	631	1.000	12.99	**0.186**	663	1.044
	83.67	631	83.64	1.000	631	1.000	12.85	**0.164**	636	1.007
cvxnonsep_normcon40	654.70	3677	658.64	1.006	3677	1.000	17.78	**0.029**	766	**0.229**
	660.04	3677	657.56	0.996	3677	1.000	17.71	**0.028**	766	**0.229**
	657.34	3677	658.24	1.001	3677	1.000	17.79	**0.029**	766	**0.229**
cvxnonsep_normcon40r	685.70	3018	685.31	0.999	3018	1.000	32.22	**0.048**	1520	**0.520**
	615.10	3050	614.77	0.999	3050	1.000	36.56	**0.061**	1573	**0.531**
	891.88	4424	893.78	1.002	4424	1.000	46.42	**0.053**	1895	**0.441**
cvxnonsep_nsig20	45.58	271	45.34	0.995	271	1.000	45.48	0.998	271	1.000
	45.65	271	45.72	1.002	271	1.000	45.78	1.003	271	1.000
	45.44	271	45.24	0.996	271	1.000	45.65	1.005	271	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
cvxnonsep_nsig20r	37.11	286	37.40	1.008	286	1.000	37.22	1.003	286	1.000
	28.35	279	28.03	0.989	279	1.000	28.49	1.005	279	1.000
	50.72	301	50.51	0.996	301	1.000	50.79	1.001	301	1.000
cvxnonsep_nsig30	948.55	1409	946.83	0.998	1409	1.000	953.89	1.006	1409	1.000
	950.23	1409	942.48	0.992	1409	1.000	949.02	0.999	1409	1.000
	950.82	1409	949.60	0.999	1409	1.000	949.63	0.999	1409	1.000
cvxnonsep_nsig30r	1963.59	4486	1960.46	0.998	4486	1.000	1960.48	0.998	4486	1.000
	2158.01	4471	2146.34	0.995	4471	1.000	2143.65	0.993	4471	1.000
	2171.93	4376	2169.98	0.999	4376	1.000	2168.16	0.998	4376	1.000
cvxnonsep_nsig40	6574.85	12265	6589.14	1.002	12265	1.000	6608.30	1.005	12265	1.000
	6569.13	12265	6585.74	1.003	12265	1.000	6593.52	1.004	12265	1.000
	6587.63	12265	6581.52	0.999	12265	1.000	6591.91	1.001	12265	1.000
cvxnonsep_nsig40r	5635.04	14920	5655.38	1.004	14920	1.000	5646.15	1.002	14920	1.000
	6244.01	16519	6240.07	0.999	16519	1.000	6241.99	1.000	16519	1.000
	6151.55	15809	6161.38	1.002	15809	1.000	6171.68	1.003	15809	1.000
cvxnonsep_pcon20	309.44	228	310.05	1.002	228	1.000	309.55	1.000	228	1.000
	308.96	228	310.01	1.003	228	1.000	311.34	1.008	228	1.000
	309.34	228	309.76	1.001	228	1.000	309.17	0.999	228	1.000
cvxnonsep_pcon20r	45.82	157	45.64	0.996	157	1.000	47.65	1.039	165	1.031
	42.87	157	42.95	1.002	157	1.000	37.06	**0.868**	165	1.031
	46.26	157	46.08	0.996	157	1.000	41.46	**0.898**	165	1.031
cvxnonsep_pcon30	1083.56	750	1087.45	1.004	750	1.000	1092.73	1.008	750	1.000
	1084.29	750	1086.75	1.002	750	1.000	1093.80	1.009	750	1.000
	1082.50	750	1089.00	1.006	750	1.000	1093.49	1.010	750	1.000
cvxnonsep_pcon30r	135.89	663	135.68	0.998	663	1.000	148.93	*1.095*	673	1.013
	124.76	613	124.59	0.999	613	1.000	149.43	*1.196*	615	1.003
	166.93	653	167.26	1.002	653	1.000	171.61	1.028	659	1.008
cvxnonsep_pcon40	1677.42	656	1677.61	1.000	656	1.000	1678.21	1.000	656	1.000
	1679.91	656	1687.15	1.004	656	1.000	1682.57	1.002	656	1.000
	1681.42	656	1682.10	1.000	656	1.000	1683.83	1.001	656	1.000
cvxnonsep_pcon40r	173.42	492	174.33	1.005	492	1.000	167.86	0.968	496	1.007
	154.03	497	153.97	1.000	497	1.000	180.46	*1.170*	501	1.007
	168.04	491	167.84	0.999	491	1.000	181.01	*1.077*	498	1.012
cvxnonsep_psig20	4.31	147	4.37	1.011	147	1.000	4.39	1.015	147	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	4.35	147	4.35	1.000	147	1.000	4.32	0.994	147	1.000
	4.36	147	4.40	1.007	147	1.000	4.34	0.996	147	1.000
cvxnonsep_psig20r	123.57	256	123.33	0.998	256	1.000	123.36	0.998	256	1.000
	36.67	239	36.70	1.001	239	1.000	36.70	1.001	239	1.000
	56.03	231	56.11	1.001	231	1.000	56.10	1.001	231	1.000
cvxnonsep_psig30	28.07	667	28.00	0.998	667	1.000	28.14	1.002	667	1.000
	28.14	667	28.37	1.008	667	1.000	28.39	1.009	667	1.000
	28.19	667	28.17	0.999	667	1.000	28.14	0.998	667	1.000
cvxnonsep_psig30r	242.52	797	243.32	1.003	797	1.000	242.76	1.001	797	1.000
	259.76	815	259.43	0.999	815	1.000	259.41	0.999	815	1.000
	268.87	820	268.96	1.000	820	1.000	269.90	1.004	820	1.000
cvxnonsep_psig40	37.21	1030	37.40	1.005	1030	1.000	37.31	1.003	1030	1.000
	37.38	1030	37.23	0.996	1030	1.000	37.15	0.994	1030	1.000
	37.25	1030	37.13	0.997	1030	1.000	37.35	1.003	1030	1.000
cvxnonsep_psig40r	92.24	890	93.00	1.008	890	1.000	92.66	1.005	890	1.000
	121.01	784	121.31	1.002	784	1.000	120.93	0.999	784	1.000
	133.51	930	133.43	0.999	930	1.000	132.62	0.993	930	1.000
densitymod	∞	7	∞	1.000	7	1.000	∞	1.000	7	1.000
	∞	7	∞	1.000	7	1.000	∞	1.000	7	1.000
	∞	7	∞	1.000	7	1.000	∞	1.000	7	1.000
du-opt5	99.77	823	99.79	1.000	823	1.000	99.63	0.999	823	1.000
	99.51	823	99.51	1.000	823	1.000	100.82	1.013	823	1.000
	100.47	823	99.51	0.991	823	1.000	100.29	0.998	823	1.000
du-opt	0.02%	57361	0.02%	1.000	54499	0.950	0.02%	1.000	44812	0.782
	0.02%	35105	0.02%	1.000	47096	1.341	0.02%	1.000	40529	1.154
	0.02%	44838	0.02%	1.000	33650	0.751	0.02%	1.000	33637	0.751
edgecross10-060	223.24%	299495	223.24%	1.000	299806	1.001	220.98%	1.000	300277	1.003
	223.24%	297868	225.53%	1.000	295279	0.991	225.53%	1.000	294908	0.990
	245.11%	290894	245.11%	1.000	289069	0.994	245.11%	1.000	290141	0.997
edgecross10-080	295.33%	962	295.33%	1.000	871	0.914	295.33%	1.000	966	1.004
	295.33%	1092	295.33%	1.000	1133	1.034	295.33%	1.000	1008	0.930
	295.33%	911	295.33%	1.000	883	0.972	295.33%	1.000	1063	1.150
edgecross14-039	∞	49011	∞	1.000	44485	0.908	∞	1.000	48596	0.992
	∞	48642	∞	1.000	48814	1.004	∞	1.000	48558	0.998

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	48992	∞	1.000	48849	0.997	∞	1.000	48870	0.998
edgecross14-078	303.46%	38822	303.46%	1.000	38856	1.001	303.46%	1.000	38984	1.004
	300.86%	38723	300.89%	1.000	38956	1.006	300.78%	1.000	39238	1.013
	301.21%	38414	301.20%	1.000	38478	1.002	301.22%	1.000	38427	1.000
edgecross14-156	57.57%	31470	57.57%	1.000	31318	0.995	57.57%	1.000	31398	0.998
	57.08%	27204	57.08%	1.000	26333	0.968	57.08%	1.000	27271	1.002
	57.19%	35714	57.20%	1.000	35921	1.006	57.20%	1.000	35645	0.998
eg_all_s	∞	21	∞	1.000	21	1.000	∞	1.000	20	0.992
	∞	12	∞	1.000	12	1.000	∞	1.000	12	1.000
eg_disc2_s	∞	16	∞	1.000	16	1.000	∞	1.000	16	1.000
	∞	14	∞	1.000	14	1.000	∞	1.000	14	1.000
	∞	16	∞	1.000	16	1.000	∞	1.000	16	1.000
eg_disc_s	∞	6	∞	1.000	6	1.000	∞	1.000	6	1.000
	∞	6	∞	1.000	6	1.000	∞	1.000	6	1.000
	∞	6	∞	1.000	6	1.000	∞	1.000	6	1.000
eg_int_s	∞	10	∞	1.000	10	1.000	∞	1.000	11	1.009
	∞	9	∞	1.000	9	1.000	∞	1.000	9	1.000
	∞	8	∞	1.000	8	1.000	∞	1.000	8	1.000
elf	10.69	313	10.69	1.000	313	1.000	15.24	*1.389*	313	1.000
	10.10	295	10.11	1.001	295	1.000	9.94	0.986	279	0.959
	11.18	297	11.11	0.994	297	1.000	11.47	1.024	297	1.000
eniplac	50.46%	1852	50.46%	1.000	1851	0.999	40.97%	1.000	3884	2.041
	48.31%	2039	48.31%	1.000	2036	0.999	41.66%	1.000	3719	1.785
	53.50%	1517	53.50%	1.000	1513	0.998	42.36%	1.000	3451	2.196
enpro48pb	484.53	1669	484.76	1.000	1669	1.000	485.60	1.002	1669	1.000
	771.16	1914	772.69	1.002	1914	1.000	772.17	1.001	1914	1.000
	682.18	1549	678.04	0.994	1549	1.000	679.93	0.997	1549	1.000
enpro56pb	0.78%	46561	0.78%	1.000	46550	1.000	1.30%	1.000	30564	0.657
	0.81%	61243	0.82%	1.000	54687	0.893	1.24%	1.000	25691	0.420
	0.08%	52369	0.08%	1.000	52337	0.999	1.34%	1.000	22774	0.436
ethanolh	341.09%	26262	341.09%	1.000	25606	0.975	341.09%	1.000	19123	0.729
	341.09%	33196	341.09%	1.000	31519	0.950	341.09%	1.000	24856	0.750
	332.77%	32344	332.77%	1.000	32768	1.013	332.77%	1.000	26306	0.814
ethanolm	341.09%	66206	341.09%	1.000	60286	0.911	341.09%	1.000	33047	0.500

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	341.09%	62423	341.09%	1.000	58779	0.942	341.09%	1.000	30331	0.487
	341.09%	59038	341.09%	1.000	50123	0.849	341.09%	1.000	30891	0.524
ex1221	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1222	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1223	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
ex1223a	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	5	1.019
ex1223b	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
ex1224	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1226	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
ex1233	302.63%	23719	302.63%	1.000	16700	0.705	252.30%	1.000	12137	0.514
	463.68%	61238	463.68%	1.000	61226	1.000	463.68%	1.000	54957	0.898
	463.68%	52200	463.68%	1.000	52745	1.010	463.68%	1.000	51485	0.986
ex1243	2539.23	13455	2538.66	1.000	13455	1.000	2531.89	0.997	13455	1.000
	2601.38	13701	2605.49	1.002	13701	1.000	2598.50	0.999	13701	1.000
	2848.05	15557	2846.21	0.999	15557	1.000	2858.07	1.004	15557	1.000
ex1244	4.75%	83979	5.00%	1.000	68894	0.821	4.99%	1.000	79174	0.943
	6.02%	70771	5.38%	1.000	78680	1.112	5.38%	1.000	79499	1.123
	5.33%	78798	5.33%	1.000	77389	0.982	5.24%	1.000	67039	0.851
ex1252	1585.80	4553	1585.16	1.000	4553	1.000	1657.35	1.045	4551	1.000
	1501.79	4771	1506.55	1.003	4771	1.000	155.63%	4.792	5611	1.172

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1722.12	4587	1719.84	0.999	4587	1.000	1719.23	0.998	4589	1.000
ex1252a	172.99%	4242	172.99%	1.000	4248	1.001	172.04%	1.000	4151	0.979
	54.16%	6137	54.16%	1.000	6138	1.000	97.36%	1.000	4378	0.718
	103.46%	4286	103.46%	1.000	4281	0.999	98.60%	1.000	4376	1.021
ex1263	347.91	16659	61.27	**0.178**	3305	**0.203**	44.38	**0.130**	2521	**0.156**
	309.16	15497	51.72	**0.170**	3248	**0.215**	45.60	**0.150**	2439	**0.163**
	336.46	16981	50.32	**0.152**	3130	**0.189**	51.65	**0.156**	3043	**0.184**
ex1263a	48.94	2195	22.40	**0.469**	1379	**0.644**	19.40	**0.408**	1155	**0.547**
	48.60	2281	28.47	**0.594**	1513	**0.677**	10.76	**0.237**	561	**0.278**
	49.06	2211	23.89	**0.497**	1372	**0.637**	11.03	**0.240**	508	**0.263**
ex1264	101.54	8265	6.39	**0.072**	607	**0.085**	6.38	**0.072**	607	**0.085**
	100.75	8697	4.36	**0.053**	326	**0.048**	4.41	**0.053**	326	**0.048**
	102.75	7487	6.94	**0.077**	656	**0.100**	6.93	**0.076**	656	**0.100**
ex1264a	188.44	7643	92.27	**0.492**	3772	**0.500**	24.75	**0.136**	1142	**0.160**
	188.06	7553	99.59	**0.532**	3868	**0.518**	69.08	**0.371**	2777	**0.376**
	189.34	7665	106.01	**0.562**	4079	**0.538**	27.58	**0.150**	1192	**0.166**
ex1265	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1265a	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1266	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex1266a	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
ex3pb	0.50	11	0.52	1.013	11	1.000	0.51	1.007	11	1.000
	0.51	11	0.50	0.993	11	1.000	0.50	0.993	11	1.000
	0.52	11	0.53	1.007	11	1.000	0.51	0.993	11	1.000
ex4	5.62	43	5.54	0.988	43	1.000	6.37	*1.113*	35	**0.944**
	11.89	73	11.99	1.008	73	1.000	12.31	1.033	65	0.954
	14.84	65	14.79	0.997	65	1.000	7.51	**0.537**	47	**0.891**

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
fac1	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.56	5	0.57	1.006	5	1.000	0.58	1.013	5	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
fac2	13.72	45	12.13	**0.892**	37	**0.945**	12.21	**0.897**	37	**0.945**
	15.81	45	14.18	**0.903**	37	**0.945**	14.18	**0.903**	37	**0.945**
	9.06	45	7.95	**0.890**	37	**0.945**	8.00	**0.895**	37	**0.945**
fac3	4.28	35	4.33	1.009	35	1.000	4.27	0.998	35	1.000
	3.76	35	3.78	1.004	35	1.000	3.73	0.994	35	1.000
	3.62	35	3.59	0.994	35	1.000	3.67	1.011	35	1.000
faclay20h	446.73%	16567	446.99%	1.000	17368	1.048	446.99%	1.000	18620	1.123
	419.97%	17570	419.78%	1.000	17924	1.020	419.75%	1.000	19126	1.088
	585.49%	15994	585.49%	1.000	15781	0.987	585.49%	1.000	15332	0.959
faclay30h	950.91%	4735	950.91%	1.000	3325	0.708	950.91%	1.000	4589	0.970
	954.86%	4390	956.21%	1.000	3368	0.772	956.21%	1.000	3372	0.773
	956.06%	3676	956.06%	1.000	3376	0.921	956.24%	1.000	3355	0.915
faclay33	1470.59%	2421	1470.59%	1.000	2420	1.000	1470.59%	1.000	2419	0.999
	1471.83%	2988	1471.83%	1.000	2787	0.935	1471.83%	1.000	2356	0.795
	1469.57%	3525	1469.57%	1.000	2661	0.762	1469.57%	1.000	3230	0.919
faclay35	1018.46%	1541	1018.46%	1.000	1548	1.004	1018.99%	1.000	1531	0.994
	1015.55%	1571	1015.55%	1.000	1570	0.999	1015.96%	1.000	2233	1.396
	1019.48%	1585	1019.48%	1.000	2725	1.677	1019.06%	1.000	1509	0.955
faclay60	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
faclay75	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
faclay80	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
feedtray	459.45%	18492	459.45%	1.000	17935	0.970	459.45%	1.000	13831	0.749
	459.45%	16695	459.45%	1.000	16235	0.973	459.45%	1.000	15249	0.914
	459.45%	11364	459.45%	1.000	15093	1.325	459.45%	1.000	12091	1.063
flay02h	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
flay02m	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
flay03h	2.38	103	2.39	1.003	103	1.000	2.40	1.006	103	1.000
	2.34	103	2.38	1.012	103	1.000	2.36	1.006	103	1.000
	2.42	103	2.47	1.015	103	1.000	2.43	1.003	103	1.000
flay03m	1.48	107	1.46	0.992	107	1.000	1.48	1.000	107	1.000
	1.50	103	1.44	0.976	103	1.000	1.48	0.992	103	1.000
	1.46	103	1.45	0.996	103	1.000	1.48	1.008	103	1.000
flay04h	179.86	3273	180.67	1.004	3273	1.000	215.76	*1.198*	3273	1.000
	176.74	3077	172.35	0.975	3081	1.001	211.00	*1.193*	3089	1.004
	175.68	3041	174.53	0.993	3041	1.000	207.71	*1.181*	3041	1.000
flay04m	549.06	6479	552.57	1.006	6479	1.000	811.09	*1.476*	8671	*1.333*
	819.36	8889	690.92	**0.843**	8023	**0.904**	551.71	**0.674**	6671	**0.753**
	844.62	9295	844.25	1.000	9295	1.000	734.51	**0.870**	8703	**0.937**
flay05h	11.27%	90575	11.27%	1.000	90431	0.998	21.89%	1.000	30323	0.336
	12.18%	89186	11.27%	1.000	89456	1.003	21.89%	1.000	30214	0.340
	11.21%	89624	11.21%	1.000	90197	1.006	20.56%	1.000	29318	0.328
flay05m	8.91%	120182	8.98%	1.000	112882	0.939	14.02%	1.000	70101	0.584
	8.71%	113281	8.71%	1.000	119568	1.055	13.07%	1.000	69200	0.611
	8.98%	111042	8.98%	1.000	115370	1.039	14.02%	1.000	68854	0.620
flay06h	49.67%	73289	49.67%	1.000	73474	1.003	52.75%	1.000	40253	0.550
	49.67%	72668	49.67%	1.000	74204	1.021	51.83%	1.000	39253	0.541
	48.74%	75128	48.93%	1.000	74656	0.994	49.67%	1.000	40076	0.534
flay06m	44.02%	170900	44.02%	1.000	162051	0.948	44.02%	1.000	115837	0.678
	44.02%	168403	44.02%	1.000	168839	1.003	46.96%	1.000	104986	0.624
	44.02%	170667	44.02%	1.000	169510	0.993	46.76%	1.000	109449	0.642
fo7	1281.99%	188440	1281.99%	1.000	189067	1.003	1202.10%	1.000	149182	0.792
	1143.49%	189159	1143.49%	1.000	189877	1.004	1281.99%	1.000	147369	0.779
	1084.56%	186056	1084.56%	1.000	189090	1.016	1281.99%	1.000	146959	0.790
fo7_2	1222.96%	164233	1222.96%	1.000	163381	0.995	$\geq$ 10000%	1.000	123665	0.753
	1195.47%	168104	1195.47%	1.000	171286	1.019	1195.47%	1.000	123612	0.735
	$\geq$ 10000%	167967	$\geq$ 10000%	1.000	169208	1.007	1222.96%	1.000	122880	0.732

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Table E.3: Detailed computational results on nonconvex instances of MINLPLIB.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
fo7_ar25_1	273.18%	159821	273.18%	1.000	161597	1.011	298.38%	1.000	110400	0.691
	273.18%	159814	273.18%	1.000	159253	0.996	291.16%	1.000	110246	0.690
	259.20%	166588	260.56%	1.000	165952	0.996	287.51%	1.000	110485	0.663
fo7_ar2_1	260.97%	175427	260.97%	1.000	175617	1.001	324.24%	1.000	109706	0.626
	276.64%	170987	276.64%	1.000	172770	1.010	292.97%	1.000	111818	0.654
	269.78%	168869	269.78%	1.000	168570	0.998	279.13%	1.000	109185	0.647
fo7_ar3_1	358.84%	151595	358.84%	1.000	152055	1.003	420.02%	1.000	107405	0.709
	358.84%	150031	358.84%	1.000	151460	1.010	403.33%	1.000	107787	0.719
	402.65%	149383	402.65%	1.000	150259	1.006	420.02%	1.000	106253	0.711
fo7_ar4_1	364.63%	148347	364.46%	1.000	152144	1.026	410.02%	1.000	112048	0.755
	358.41%	154355	357.84%	1.000	155965	1.010	411.67%	1.000	113808	0.737
	382.39%	144724	382.39%	1.000	151648	1.048	395.01%	1.000	114231	0.789
fo7_ar5_1	423.61%	130360	423.61%	1.000	130849	1.004	429.17%	1.000	97800	0.750
	406.04%	130367	406.04%	1.000	127903	0.981	429.17%	1.000	99800	0.766
	406.03%	130564	406.03%	1.000	130357	0.998	429.17%	1.000	97239	0.745
fo8	∞	173787	∞	1.000	173597	0.999	∞	1.000	148719	0.856
	∞	173426	∞	1.000	173313	0.999	∞	1.000	149261	0.861
	∞	171943	∞	1.000	171753	0.999	∞	1.000	146800	0.854
fo8_ar25_1	1008.59%	159938	1008.59%	1.000	161096	1.007	1008.59%	1.000	135911	0.850
	1008.59%	160239	1008.59%	1.000	161138	1.006	1008.59%	1.000	133579	0.834
	1008.59%	160399	1008.59%	1.000	158902	0.991	1008.59%	1.000	134759	0.840
fo8_ar2_1	972.71%	166397	972.71%	1.000	162730	0.978	972.71%	1.000	131168	0.788
	972.71%	158779	972.71%	1.000	160173	1.009	972.71%	1.000	129983	0.819
	972.71%	165000	972.71%	1.000	163352	0.990	972.71%	1.000	130185	0.789
fo8_ar3_1	935.34%	154641	935.34%	1.000	154788	1.001	935.34%	1.000	127940	0.827
	935.34%	151932	935.34%	1.000	150708	0.992	935.34%	1.000	128478	0.846
	935.34%	151788	935.34%	1.000	152144	1.002	935.34%	1.000	126548	0.834
fo8_ar4_1	1019.09%	151698	1019.09%	1.000	151746	1.000	1019.09%	1.000	127676	0.842
	1001.74%	146626	1001.74%	1.000	146786	1.001	1019.09%	1.000	125184	0.854
	1019.09%	148652	1019.09%	1.000	145981	0.982	1001.74%	1.000	125939	0.847
fo8_ar5_1	1151.15%	139429	1151.15%	1.000	138850	0.996	1151.15%	1.000	118634	0.851
	1151.15%	137727	1151.15%	1.000	136042	0.988	1151.15%	1.000	117169	0.851
	1151.15%	136774	1151.15%	1.000	135933	0.994	1151.15%	1.000	116295	0.850
fo9	∞	157092	∞	1.000	157143	1.000	∞	1.000	143422	0.913

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	156079	∞	1.000	154897	0.992	∞	1.000	143624	0.920
	∞	156993	∞	1.000	153514	0.978	∞	1.000	143511	0.914
fo9_ar25_1	1172.29%	144546	1172.29%	1.000	146696	1.015	1172.29%	1.000	128049	0.886
	1172.29%	144824	1172.29%	1.000	142328	0.983	1172.29%	1.000	126575	0.874
	1172.29%	143266	1172.29%	1.000	146175	1.020	1172.29%	1.000	126426	0.883
fo9_ar2_1	1053.48%	143183	1053.48%	1.000	142402	0.995	1053.48%	1.000	128342	0.896
	1053.48%	141788	1053.48%	1.000	141400	0.997	1053.48%	1.000	128496	0.906
	1053.48%	143173	1053.48%	1.000	143645	1.003	1053.48%	1.000	127331	0.889
fo9_ar3_1	974.54%	131144	974.54%	1.000	130219	0.993	974.54%	1.000	117434	0.896
	974.54%	129521	974.54%	1.000	129095	0.997	974.54%	1.000	118083	0.912
	974.54%	130210	974.54%	1.000	130273	1.000	974.54%	1.000	117004	0.899
fo9_ar4_1	1073.21%	136249	1073.21%	1.000	133808	0.982	1073.21%	1.000	121277	0.890
	1073.21%	134898	1073.21%	1.000	134768	0.999	1073.21%	1.000	121483	0.901
	1073.21%	132142	1073.21%	1.000	134861	1.021	1073.21%	1.000	118941	0.900
fo9_ar5_1	1211.66%	122614	1211.66%	1.000	123192	1.005	1211.66%	1.000	112149	0.915
	1211.66%	122138	1211.66%	1.000	122096	1.000	1211.66%	1.000	109993	0.901
	1211.66%	122962	1211.66%	1.000	122893	0.999	1211.66%	1.000	112227	0.913
forest	∞	795	∞	1.000	795	1.000	∞	1.000	795	1.000
	∞	622	∞	1.000	622	1.000	∞	1.000	622	1.000
	∞	635	∞	1.000	635	1.000	∞	1.000	635	1.000
fuel	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
fuzzy	85.98%	174	85.98%	1.000	174	1.000	85.98%	1.000	174	1.000
	85.98%	172	85.98%	1.000	2406	9.213	85.98%	1.000	172	1.000
	85.98%	179	85.98%	1.000	179	1.000	85.98%	1.000	179	1.000
gabriel01	∞	58584	∞	1.000	59616	1.018	∞	1.000	59917	1.023
	∞	15701	∞	1.000	61207	3.880	∞	1.000	61123	3.875
	∞	64284	∞	1.000	41577	0.647	∞	1.000	41014	0.639
gabriel02	∞	42945	∞	1.000	42355	0.986	∞	1.000	43308	1.008
	∞	46093	∞	1.000	45053	0.977	∞	1.000	45873	0.995
	∞	40879	∞	1.000	40511	0.991	∞	1.000	43198	1.057
gabriel04	∞	20592	∞	1.000	20826	1.011	∞	1.000	23807	1.155
	∞	22289	∞	1.000	22352	1.003	∞	1.000	24779	1.111

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	21249	∞	1.000	21214	0.998	∞	1.000	23283	1.095
gabriel05	∞	21750	∞	1.000	21716	0.998	∞	1.000	21802	1.002
	∞	22825	∞	1.000	21761	0.954	∞	1.000	22184	0.972
	∞	21691	∞	1.000	21616	0.997	∞	1.000	20437	0.942
gabriel06	∞	3107	∞	1.000	3096	0.997	∞	1.000	3640	1.166
	∞	3125	∞	1.000	3028	0.970	∞	1.000	3025	0.969
	∞	2262	∞	1.000	2261	1.000	∞	1.000	2303	1.017
gabriel07	∞	3809	∞	1.000	4717	1.232	∞	1.000	3814	1.001
	∞	3678	∞	1.000	4446	1.203	∞	1.000	3895	1.057
	∞	4697	∞	1.000	3942	0.843	∞	1.000	3878	0.829
gabriel08	∞	844	∞	1.000	839	0.995	∞	1.000	838	0.994
	∞	848	∞	1.000	850	1.002	∞	1.000	873	1.026
gabriel09	∞	988	∞	1.000	985	0.997	∞	1.000	1615	1.576
	∞	2091	∞	1.000	1907	0.916	∞	1.000	1903	0.914
	∞	2233	∞	1.000	2486	1.108	∞	1.000	2638	1.174
gabriel10	∞	56	∞	1.000	56	1.000	∞	1.000	56	1.000
	∞	59	∞	1.000	59	1.000	∞	1.000	59	1.000
	∞	56	∞	1.000	57	1.006	∞	1.000	56	1.000
gams01	2522.21%	7710	2517.09%	1.000	8924	1.155	2516.37%	1.000	8404	1.089
	2534.08%	7973	2514.73%	1.000	7837	0.983	2515.76%	1.000	6871	0.863
	2776.57%	8804	2474.22%	1.000	9393	1.066	2474.49%	1.000	8703	0.989
gams02	≥ 10000%	12867	≥ 10000%	1.000	12623	0.981	≥ 10000%	1.000	13282	1.032
	≥ 10000%	12299	≥ 10000%	1.000	12520	1.018	≥ 10000%	1.000	12778	1.039
	≥ 10000%	8926	≥ 10000%	1.000	8481	0.951	≥ 10000%	1.000	9056	1.014
gams03	7982.61%	5700	7982.61%	1.000	6404	1.121	7982.61%	1.000	6371	1.116
	7982.61%	6861	7982.61%	1.000	6791	0.990	7982.61%	1.000	6792	0.990
	7982.61%	7035	7982.61%	1.000	6642	0.945	7982.61%	1.000	6590	0.938
gasnet	208.95%	963	208.95%	1.000	959	0.996	208.19%	1.000	1042	1.074
	209.10%	848	209.10%	1.000	848	1.000	209.10%	1.000	933	1.090
	208.45%	768	208.45%	1.000	768	1.000	208.45%	1.000	3022	3.597
gasnet_al1	∞	15797	∞	1.000	11929	0.757	∞	1.000	11518	0.731
	∞	14199	∞	1.000	11391	0.804	∞	1.000	11307	0.798
	∞	13177	∞	1.000	11238	0.854	∞	1.000	12310	0.935
gasnet_al2	∞	14946	∞	1.000	14801	0.990	∞	1.000	11400	0.764

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	13675	∞	1.000	13189	0.965	∞	1.000	11883	0.870
	∞	14033	∞	1.000	12822	0.914	∞	1.000	12192	0.870
gasnet_al3	∞	15639	∞	1.000	14724	0.942	∞	1.000	13995	0.896
	∞	13196	∞	1.000	12438	0.943	∞	1.000	11741	0.891
	∞	11433	∞	1.000	15871	1.385	∞	1.000	11640	1.018
gasnet_al4	∞	13771	∞	1.000	15591	1.131	∞	1.000	12448	0.905
	∞	11004	∞	1.000	15609	1.415	∞	1.000	11133	1.012
	∞	12819	∞	1.000	11270	0.880	∞	1.000	11603	0.906
gasnet_al5	∞	13273	∞	1.000	13692	1.031	∞	1.000	11165	0.842
	∞	15100	∞	1.000	15685	1.038	∞	1.000	11754	0.780
	∞	11998	∞	1.000	13701	1.141	∞	1.000	12392	1.033
gasprod_sarawak01	29.09	287	29.10	1.000	287	1.000	29.19	1.003	287	1.000
	13.61	137	13.49	0.992	137	1.000	13.41	0.986	137	1.000
	13.45	137	13.31	0.990	137	1.000	13.48	1.002	137	1.000
gasprod_sarawak16	0.47%	531	0.47%	1.000	531	1.000	0.47%	1.000	531	1.000
	2.58%	4816	2.58%	1.000	5092	1.056	2.58%	1.000	4813	0.999
	2.54%	7335	2.54%	1.000	7537	1.027	2.54%	1.000	5148	0.706
gasprod_sarawak81	3.00%	162	3.00%	1.000	162	1.000	3.00%	1.000	162	1.000
	3.20%	33	3.20%	1.000	33	1.000	3.20%	1.000	33	1.000
	2.08%	621	2.08%	1.000	613	0.989	2.08%	1.000	611	0.986
gastrans582_freezing27	∞	62	∞	1.000	61	0.994	∞	1.000	62	1.000
	∞	67	∞	1.000	67	1.000	∞	1.000	67	1.000
	∞	54	∞	1.000	54	1.000	∞	1.000	54	1.000
gastrans582_freezing27_95	∞	63	∞	1.000	63	1.000	∞	1.000	63	1.000
	∞	63	∞	1.000	63	1.000	∞	1.000	63	1.000
	∞	59	∞	1.000	59	1.000	∞	1.000	59	1.000
gastrans	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
gbd	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
gear4	22.98	5453	22.73	0.990	5453	1.000	22.69	0.988	5453	1.000
	22.59	5453	22.71	1.005	5453	1.000	22.91	1.014	5453	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	22.72	5453	22.79	1.003	5453	1.000	22.54	0.992	5453	1.000
genpooling_lee1	37.21%	14	37.21%	1.000	15	1.009	37.21%	1.000	16	1.018
	37.21%	14	37.21%	1.000	16	1.018	37.21%	1.000	15	1.009
	37.21%	14	37.21%	1.000	14	1.000	37.21%	1.000	15	1.009
genpooling_lee2	65.39%	7	65.39%	1.000	9	1.019	65.39%	1.000	7	1.000
	65.39%	9	65.39%	1.000	7	0.982	65.39%	1.000	7	0.982
	65.39%	9	65.39%	1.000	9	1.000	65.39%	1.000	9	1.000
genpooling_meyer04	150.34%	170991	150.34%	1.000	170915	1.000	150.34%	1.000	171384	1.002
	132.82%	136386	132.82%	1.000	135938	0.997	132.82%	1.000	136488	1.001
	149.24%	148068	149.24%	1.000	148260	1.001	149.24%	1.000	148602	1.004
genpooling_meyer10	214.25%	20375	214.25%	1.000	19693	0.967	214.25%	1.000	19747	0.969
	189.71%	21710	189.71%	1.000	21890	1.008	189.71%	1.000	21651	0.997
	214.89%	18589	214.89%	1.000	18593	1.000	214.89%	1.000	18657	1.004
genpooling_meyer15	99.84%	9297	99.84%	1.000	8886	0.956	99.84%	1.000	9818	1.055
	105.17%	398	105.17%	1.000	398	1.000	105.17%	1.000	398	1.000
	99.84%	9490	99.84%	1.000	10115	1.065	99.84%	1.000	10115	1.065
ghg_1veh	4.82%	10414	4.76%	1.000	10845	1.041	4.83%	1.000	8226	0.792
	5.01%	10814	5.01%	1.000	9773	0.905	5.13%	1.000	8091	0.751
	4.86%	10267	4.87%	1.000	10671	1.039	5.09%	1.000	7983	0.780
ghg_2veh	275.89%	9395	279.16%	1.000	6531	0.698	286.41%	1.000	6825	0.729
	279.67%	10716	∞	1.000	11160	1.041	282.58%	1.000	6989	0.655
	255.75%	10199	254.07%	1.000	7254	0.714	245.53%	1.000	8164	0.802
ghg_3veh	∞	11058	∞	1.000	12433	1.123	∞	1.000	10948	0.990
	∞	12623	∞	1.000	13884	1.099	∞	1.000	9657	0.767
	∞	12297	∞	1.000	10452	0.851	∞	1.000	10153	0.827
gkocis	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
graphpart_2g-0044-1601	188.72	27049	188.48	0.999	27049	1.000	188.60	0.999	27049	1.000
	179.90	25729	179.65	0.999	25729	1.000	180.05	1.001	25729	1.000
	180.09	25887	180.60	1.003	25887	1.000	180.82	1.004	25887	1.000
graphpart_2g-0055-0062	27.05%	604618	27.05%	1.000	603108	0.998	27.05%	1.000	603957	0.999
	27.05%	626175	27.05%	1.000	624184	0.997	27.05%	1.000	624506	0.997
	27.05%	602426	27.05%	1.000	604062	1.003	27.05%	1.000	603137	1.001

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
graphpart_2g-0066-0066	27.09%	429669	27.09%	1.000	431192	1.004	27.09%	1.000	431290	1.004
	27.09%	431419	27.09%	1.000	430763	0.998	27.09%	1.000	433367	1.005
	27.09%	434794	27.09%	1.000	431613	0.993	27.09%	1.000	431393	0.992
graphpart_2g-0077-0077	19.81%	413925	19.81%	1.000	414763	1.002	19.81%	1.000	415430	1.004
	19.81%	421812	19.81%	1.000	421816	1.000	19.81%	1.000	422173	1.001
	19.81%	419472	19.81%	1.000	419432	1.000	19.81%	1.000	420283	1.002
graphpart_2g-0088-0088	27.06%	310587	27.06%	1.000	311455	1.003	27.06%	1.000	311198	1.002
	27.06%	315053	27.06%	1.000	314476	0.998	27.06%	1.000	316298	1.004
	27.06%	315478	27.06%	1.000	315568	1.000	27.06%	1.000	317180	1.005
graphpart_2g-0099-9211	21.89%	297218	21.89%	1.000	297262	1.000	21.89%	1.000	296859	0.999
	21.89%	297330	21.89%	1.000	298468	1.004	21.89%	1.000	298595	1.004
	21.89%	297707	21.89%	1.000	298362	1.002	21.89%	1.000	297921	1.001
graphpart_2g-1010-0824	42.34%	235297	42.34%	1.000	235978	1.003	42.34%	1.000	235913	1.003
	42.34%	231053	42.34%	1.000	231683	1.003	42.34%	1.000	231582	1.002
	42.34%	234673	42.34%	1.000	234064	0.997	42.34%	1.000	230188	0.981
graphpart_3g-0234-0234	73.70%	456517	73.70%	1.000	455742	0.998	73.70%	1.000	454870	0.996
	73.70%	456709	73.70%	1.000	456013	0.998	73.70%	1.000	459285	1.006
	73.70%	455356	73.70%	1.000	456810	1.003	73.70%	1.000	458936	1.008
graphpart_3g-0244-0244	67.45%	394396	67.45%	1.000	392885	0.996	67.45%	1.000	394975	1.001
	67.45%	396386	67.45%	1.000	394930	0.996	67.45%	1.000	397175	1.002
	67.45%	393343	67.45%	1.000	394940	1.004	67.45%	1.000	395084	1.004
graphpart_3g-0333-0333	64.71%	480729	64.71%	1.000	479084	0.997	64.71%	1.000	481084	1.001
	64.71%	452675	64.71%	1.000	449811	0.994	64.71%	1.000	448798	0.991
	64.71%	481445	64.71%	1.000	476879	0.991	64.71%	1.000	477315	0.991
graphpart_3g-0334-0334	54.22%	381581	54.22%	1.000	381964	1.001	54.22%	1.000	383869	1.006
	54.22%	384826	54.22%	1.000	382993	0.995	54.22%	1.000	383513	0.997
	54.22%	384582	54.22%	1.000	386675	1.005	54.22%	1.000	386865	1.006
graphpart_3g-0344-0344	59.74%	323610	59.74%	1.000	323700	1.000	59.74%	1.000	323316	0.999
	59.74%	324159	59.74%	1.000	324351	1.001	59.74%	1.000	321777	0.993
	59.74%	325500	59.74%	1.000	324504	0.997	59.74%	1.000	320772	0.985
graphpart_3g-0444-0444	58.62%	275635	58.62%	1.000	279364	1.014	58.62%	1.000	280073	1.016
	58.62%	278214	58.62%	1.000	278105	1.000	58.62%	1.000	278217	1.000
	58.62%	279095	58.62%	1.000	277200	0.993	58.62%	1.000	278962	1.000
hda	1028.44%	3231	1028.44%	1.000	3601	1.111	826.44%	1.000	4059	1.249

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1028.44%	3330	1028.44%	1.000	3330	1.000	1028.44%	1.000	3985	1.191
	2061.80%	3129	2061.80%	1.000	3129	1.000	2173.08%	1.000	3408	1.086
heatexch_gen1	54.13%	34039	54.13%	1.000	34243	1.006	54.13%	1.000	29372	0.863
	54.13%	34167	54.13%	1.000	34077	0.997	54.13%	1.000	29361	0.860
	54.13%	34226	54.13%	1.000	34576	1.010	54.13%	1.000	30905	0.903
heatexch_gen2	9.35%	9184	9.35%	1.000	9841	1.071	9.35%	1.000	10525	1.144
	9.35%	38196	9.35%	1.000	37574	0.984	9.35%	1.000	43686	1.143
	9.35%	11856	9.35%	1.000	11857	1.000	9.35%	1.000	12013	1.013
heatexch_gen3	30.55%	23428	24.68%	1.000	23596	1.007	24.68%	1.000	23547	1.005
	25.91%	22978	34.26%	1.000	20426	0.889	34.26%	1.000	20687	0.901
	30.27%	23143	32.60%	1.000	21147	0.914	32.60%	1.000	21136	0.914
heatexch_spec1	41.12%	25953	41.12%	1.000	25515	0.983	34.49%	1.000	11666	0.452
	41.12%	25208	41.12%	1.000	24986	0.991	41.12%	1.000	15381	0.612
	41.12%	23854	41.12%	1.000	23581	0.989	39.45%	1.000	14062	0.591
heatexch_spec2	28.59%	18467	28.59%	1.000	19054	1.032	34.13%	1.000	22428	1.213
	33.90%	22523	33.90%	1.000	20757	0.922	19.52%	1.000	23850	1.059
	23.85%	21547	23.85%	1.000	21234	0.986	27.33%	1.000	20817	0.966
heatexch_spec3	160.24%	10581	149.61%	1.000	11234	1.061	149.61%	1.000	11234	1.061
	160.24%	8950	151.47%	1.000	11049	1.232	151.47%	1.000	10708	1.194
	162.36%	11721	162.45%	1.000	11639	0.993	162.45%	1.000	11741	1.002
heatexch_trigen	1.03%	7923131	1.03%	1.000	7919730	1.000	1.03%	1.000	7932044	1.001
	1.03%	7820327	1.03%	1.000	7766199	0.993	1.03%	1.000	7729272	0.988
	1.03%	7707318	1.03%	1.000	7709004	1.000	1.03%	1.000	7702495	0.999
hvb11	187.77%	3135	154.27%	1.000	6202	1.948	154.27%	1.000	8925	2.790
	152.26%	9332	183.66%	1.000	2475	0.273	183.66%	1.000	2475	0.273
	152.26%	9779	239.63%	1.000	2990	0.313	239.63%	1.000	2989	0.313
hybriddynamic_var	618.55	4352	616.88	0.997	4352	1.000	617.57	0.998	4352	1.000
	571.16	4327	571.67	1.001	4327	1.000	571.14	1.000	4327	1.000
	666.39	4582	665.59	0.999	4582	1.000	666.60	1.000	4582	1.000
hydroenergy1	2.33%	38939	2.34%	1.000	38350	0.985	2.33%	1.000	38895	0.999
	2.34%	37638	2.34%	1.000	37252	0.990	2.34%	1.000	36989	0.983
	2.34%	38133	2.34%	1.000	38077	0.999	2.34%	1.000	36296	0.952
hydroenergy2	2.59%	22421	2.59%	1.000	22349	0.997	2.59%	1.000	21832	0.974
	2.59%	22112	2.59%	1.000	20923	0.946	2.59%	1.000	21822	0.987

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	2.59%	21691	2.59%	1.000	21238	0.979	2.59%	1.000	20956	0.966
hydroenergy3	3.09%	14289	3.09%	1.000	13783	0.965	3.09%	1.000	15852	1.109
	3.09%	14059	3.09%	1.000	15939	1.133	3.09%	1.000	15036	1.069
	3.11%	15616	3.11%	1.000	15855	1.015	3.11%	1.000	15590	0.998
ibs2	0.22%	144	0.22%	1.000	144	1.000	0.22%	1.000	144	1.000
	0.22%	220	0.22%	1.000	220	1.000	0.22%	1.000	220	1.000
	0.22%	106	0.22%	1.000	106	1.000	0.22%	1.000	106	1.000
ising2_5-300_5555	∞	6026	∞	1.000	6124	1.016	∞	1.000	6140	1.019
	∞	5946	∞	1.000	5997	1.008	∞	1.000	6317	1.061
	∞	6056	∞	1.000	6128	1.012	∞	1.000	5942	0.981
jit1	3.45	15	3.47	1.004	15	1.000	3.68	*1.052*	13	0.983
	4.51	19	4.51	1.000	19	1.000	3.76	**0.864**	11	**0.933**
	4.21	13	4.23	1.004	13	1.000	13.30	*2.745*	31	*1.159*
johnall	2.78%	47	2.78%	1.000	47	1.000	2.78%	1.000	47	1.000
	2.78%	100	2.78%	1.000	100	1.000	2.78%	1.000	100	1.000
	2.76%	54	2.76%	1.000	54	1.000	2.76%	1.000	54	1.000
kport20	13.92%	154565	13.92%	1.000	153963	0.996	13.92%	1.000	278213	1.799
	13.92%	154779	13.92%	1.000	154185	0.996	13.92%	1.000	290584	1.877
	13.92%	153867	13.92%	1.000	153660	0.999	13.92%	1.000	285919	1.858
kport40	19.91%	104258	19.91%	1.000	104675	1.004	19.91%	1.000	127363	1.221
	19.91%	94086	19.91%	1.000	94362	1.003	19.91%	1.000	132114	1.404
	19.91%	104389	19.91%	1.000	104516	1.001	19.91%	1.000	123789	1.186
lip	67.65%	44790	67.65%	1.000	60114	1.341	67.65%	1.000	58985	1.316
	1.58%	62273	66.10%	1.000	63090	1.013	66.10%	1.000	63851	1.025
	1.57%	53552	1.57%	1.000	49681	0.928	1.57%	1.000	38140	0.713
lop97ic	59.73%	13223	59.73%	1.000	13542	1.024	59.73%	1.000	13448	1.017
	59.73%	14090	59.73%	1.000	13811	0.980	59.73%	1.000	14083	1.000
	59.73%	8389	59.73%	1.000	8966	1.068	59.73%	1.000	8878	1.058
lop97icx	61.07%	86494	61.07%	1.000	87279	1.009	61.07%	1.000	85297	0.986
	61.07%	85115	61.07%	1.000	85800	1.008	61.07%	1.000	87819	1.032
	61.07%	89072	61.07%	1.000	90850	1.020	61.07%	1.000	89353	1.003
m3	1.41	41	1.40	0.996	41	1.000	1.42	1.004	41	1.000
	1.39	41	1.34	0.979	41	1.000	1.37	0.992	41	1.000
	1.40	41	1.35	0.979	41	1.000	1.38	0.992	41	1.000

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Table E.3: Detailed computational results on nonconvex instances of MINLPLIB.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
m6	40.73%	155045	30.11%	1.000	149434	0.964	83.13%	1.000	86776	0.560
	45.45%	159900	33.50%	1.000	147555	0.923	79.62%	1.000	85596	0.536
	41.95%	160079	37.09%	1.000	153163	0.957	80.75%	1.000	86757	0.542
m7	1168.26%	161949	890.33%	1.000	161786	0.999	∞	1.000	93025	0.575
	1168.26%	163771	1168.26%	1.000	160385	0.979	∞	1.000	92497	0.565
	∞	163107	1168.26%	1.000	153648	0.942	∞	1.000	92511	0.567
m7_ar25_1	1159.16	17897	1209.97	1.044	18870	*1.054*	1446.82	*1.248*	19703	*1.100*
	1163.33	17565	1199.00	1.031	18518	*1.054*	1346.30	*1.157*	18035	1.027
	1157.62	17651	1065.82	**0.921**	16438	**0.932**	1386.53	*1.198*	18486	1.047
m7_ar2_1	971.28	19929	957.44	0.986	19909	0.999	1168.60	*1.203*	20623	1.035
	963.72	19959	958.63	0.995	19789	0.992	1093.90	*1.135*	19710	0.988
	998.14	20865	960.70	0.963	20343	0.975	1123.40	*1.125*	20023	0.960
m7_ar3_1	71.44%	146387	74.35%	1.000	151458	1.035	102.50%	1.000	83467	0.570
	68.17%	145712	72.90%	1.000	141714	0.973	112.56%	1.000	82965	0.570
	69.65%	144435	69.29%	1.000	146626	1.015	106.94%	1.000	82166	0.569
m7_ar4_1	229.13%	128996	227.69%	1.000	122751	0.952	325.81%	1.000	75128	0.583
	160.43%	126196	179.89%	1.000	126962	1.006	278.62%	1.000	75702	0.600
	177.45%	132615	169.46%	1.000	134912	1.017	261.85%	1.000	75755	0.572
m7_ar5_1	280.23%	130484	317.93%	1.000	125632	0.963	370.07%	1.000	76483	0.586
	296.26%	126836	313.58%	1.000	133499	1.052	354.42%	1.000	74592	0.588
	308.61%	130615	314.20%	1.000	126488	0.968	376.88%	1.000	76454	0.586
meanvar-orl400_05_e_7	∞	217	∞	1.000	217	1.000	∞	1.000	217	1.000
	∞	294	∞	1.000	294	1.000	∞	1.000	294	1.000
	∞	226	∞	1.000	226	1.000	∞	1.000	226	1.000
meanvar-orl400_05_e_8	15.62%	694	15.62%	1.000	730	1.045	15.62%	1.000	690	0.995
	11.77%	481	11.77%	1.000	480	0.998	11.77%	1.000	502	1.036
	12.94%	512	12.94%	1.000	517	1.008	12.94%	1.000	522	1.016
meanvarx	6.35	25	6.30	0.993	25	1.000	6.32	0.996	25	1.000
	3.12	23	3.13	1.002	23	1.000	3.16	1.010	23	1.000
	6.82	19	6.97	1.019	19	1.000	6.94	1.015	19	1.000
meanvarxsc	4.89	13	4.96	1.012	13	1.000	4.97	1.014	13	1.000
	4.64	13	4.65	1.002	13	1.000	4.67	1.005	13	1.000
	4.56	13	4.61	1.009	13	1.000	4.60	1.007	13	1.000
milinfract	0.00%	474	0.00%	1.000	378	0.833	0.00%	1.000	274	0.652

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.00%	394	0.00%	1.000	357	0.925	0.00%	1.000	518	1.251
	0.00%	309	0.00%	1.000	234	0.817	0.00%	1.000	336	1.066
minlphix	∞	6062	∞	1.000	18977	3.096	∞	1.000	8253	1.356
	∞	11200	∞	1.000	1379	0.131	∞	1.000	1380	0.131
	∞	2037	∞	1.000	2037	1.000	∞	1.000	2025	0.994
multiplants_mtg1a	3628.47%	6865	4260.87%	1.000	13195	1.909	3619.40%	1.000	9593	1.392
	5070.77%	4006	5055.80%	1.000	4171	1.040	4898.65%	1.000	10913	2.682
	4875.48%	5783	4896.93%	1.000	5357	0.928	4406.17%	1.000	8518	1.465
multiplants_mtg1b	$\geq$ 10000%	12326	$\geq$ 10000%	1.000	4782	0.393	$\geq$ 10000%	1.000	13196	1.070
	$\geq$ 10000%	16280	$\geq$ 10000%	1.000	5894	0.366	$\geq$ 10000%	1.000	15261	0.938
	$\geq$ 10000%	4473	$\geq$ 10000%	1.000	4552	1.017	$\geq$ 10000%	1.000	5710	1.271
multiplants_mtg1c	$\geq$ 10000%	9975	$\geq$ 10000%	1.000	7391	0.744	$\geq$ 10000%	1.000	8710	0.874
	$\geq$ 10000%	5434	$\geq$ 10000%	1.000	5813	1.068	$\geq$ 10000%	1.000	11790	2.149
	$\geq$ 10000%	6148	$\geq$ 10000%	1.000	7121	1.156	$\geq$ 10000%	1.000	10439	1.687
multiplants_mtg2	587.52%	1690	587.72%	1.000	1291	0.777	587.72%	1.000	6457	3.663
	588.71%	1519	587.52%	1.000	1890	1.229	587.94%	1.000	2015	1.306
	588.71%	1380	588.04%	1.000	1638	1.174	588.04%	1.000	1779	1.270
multiplants_mtg5	923.73%	3092	923.73%	1.000	3170	1.024	923.73%	1.000	5135	1.640
	923.73%	2423	923.73%	1.000	2454	1.012	923.73%	1.000	4036	1.639
	923.73%	2465	923.73%	1.000	2204	0.898	923.73%	1.000	3372	1.354
multiplants_mtg6	1720.17%	509	1720.17%	1.000	6271	10.461	1720.17%	1.000	585	1.125
	1720.17%	307	1720.17%	1.000	307	1.000	1720.17%	1.000	315	1.020
	1720.17%	403	1720.17%	1.000	404	1.002	1720.17%	1.000	404	1.002
multiplants_stg1	4068.14%	8482	4068.14%	1.000	9585	1.129	4068.14%	1.000	9499	1.119
	4068.14%	7765	4068.14%	1.000	6368	0.822	4068.14%	1.000	5982	0.773
	4068.14%	7728	4068.14%	1.000	9761	1.260	4068.14%	1.000	9056	1.170
multiplants_stg1a	2744.20%	14736	2744.20%	1.000	18090	1.226	2744.20%	1.000	15451	1.048
	2744.20%	18597	2744.20%	1.000	14664	0.790	2744.20%	1.000	15632	0.841
	2744.20%	18628	2744.20%	1.000	21478	1.152	2744.20%	1.000	18206	0.977
multiplants_stg1b	5458.03%	3110	5458.03%	1.000	2251	0.732	5458.03%	1.000	2251	0.732
	5458.03%	1749	5458.03%	1.000	2231	1.261	5458.03%	1.000	2974	1.663
	5458.03%	3155	5458.03%	1.000	2199	0.706	5458.03%	1.000	2199	0.706
multiplants_stg1c	2680.68%	5164	2680.68%	1.000	5363	1.038	2680.68%	1.000	2831	0.557
	2680.68%	3706	2680.68%	1.000	5219	1.398	2680.68%	1.000	4930	1.322

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	2680.68%	4971	2680.68%	1.000	6118	1.226	2680.68%	1.000	5666	1.137
multiplants_stg5	1308.28%	15486	1308.28%	1.000	8158	0.530	1308.28%	1.000	6128	0.400
	1308.28%	13940	1308.28%	1.000	7307	0.528	1308.28%	1.000	10683	0.768
	1308.28%	7442	1308.28%	1.000	6130	0.826	1308.28%	1.000	10228	1.369
multiplants_stg6	1827.37%	2886	1827.37%	1.000	2953	1.022	1827.37%	1.000	3025	1.047
	1827.37%	2937	1827.37%	1.000	2951	1.005	1827.37%	1.000	2855	0.973
	1827.37%	2671	1827.37%	1.000	2472	0.928	1827.37%	1.000	2771	1.036
nd_netgen-2000-2-5-a-a-ns_7	∞	31	∞	1.000	31	1.000	∞	1.000	31	1.000
	∞	30	∞	1.000	30	1.000	∞	1.000	30	1.000
	∞	30	∞	1.000	30	1.000	∞	1.000	30	1.000
nd_netgen-2000-3-4-b-a-ns_7	∞	31	∞	1.000	31	1.000	∞	1.000	31	1.000
	∞	32	∞	1.000	32	1.000	∞	1.000	33	1.008
	∞	32	∞	1.000	32	1.000	∞	1.000	32	1.000
nd_netgen-3000-1-1-b-b-ns_7	21.88	1	21.75	0.994	1	1.000	21.85	0.999	1	1.000
	8.09	1	8.12	1.003	1	1.000	8.13	1.004	1	1.000
	38.08	3	38.08	1.000	3	1.000	38.11	1.001	3	1.000
ndcc12	138.83%	26322	138.83%	1.000	26582	1.010	138.83%	1.000	26202	0.995
	138.93%	27369	138.93%	1.000	28905	1.056	138.93%	1.000	28184	1.030
	133.58%	30117	133.58%	1.000	29601	0.983	133.58%	1.000	29496	0.979
ndcc12persp	156.19%	1413	156.19%	1.000	1413	1.000	156.19%	1.000	1413	1.000
	147.94%	42780	147.94%	1.000	43844	1.025	147.94%	1.000	35451	0.829
	148.81%	16845	148.81%	1.000	16845	1.000	148.81%	1.000	16845	1.000
ndcc13	46.97%	2741	46.97%	1.000	2741	1.000	46.97%	1.000	2741	1.000
	45.78%	2713	45.78%	1.000	2713	1.000	45.78%	1.000	2713	1.000
	41.35%	4049	41.35%	1.000	4049	1.000	41.35%	1.000	4049	1.000
ndcc13persp	32.69%	30201	32.69%	1.000	31050	1.028	32.69%	1.000	21862	0.725
	40.16%	26248	40.16%	1.000	26595	1.013	40.16%	1.000	22872	0.872
	40.16%	26732	40.16%	1.000	19652	0.736	40.16%	1.000	28441	1.064
ndcc14	122.74%	6453	122.74%	1.000	6453	1.000	122.74%	1.000	6453	1.000
	119.78%	9225	119.78%	1.000	6067	0.661	119.78%	1.000	9626	1.043
	119.78%	6460	119.78%	1.000	9028	1.391	119.78%	1.000	8253	1.273
ndcc14persp	123.86%	14832	123.86%	1.000	14832	1.000	123.86%	1.000	14832	1.000
	123.86%	25798	123.86%	1.000	24839	0.963	123.86%	1.000	27213	1.055
	123.86%	16358	123.86%	1.000	22192	1.354	123.86%	1.000	16364	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
ndcc15	59.06%	6777	59.06%	1.000	6777	1.000	59.06%	1.000	6777	1.000
	50.63%	2174	50.63%	1.000	2174	1.000	50.63%	1.000	2174	1.000
	54.66%	15174	54.66%	1.000	9705	0.642	54.66%	1.000	9838	0.651
ndcc15persp	41.95%	15704	41.95%	1.000	15707	1.000	41.95%	1.000	15695	0.999
	49.52%	24389	49.52%	1.000	24009	0.984	49.52%	1.000	19497	0.800
	34.47%	21058	34.47%	1.000	20340	0.966	34.47%	1.000	22105	1.049
ndcc16	155.67%	860	155.67%	1.000	860	1.000	155.67%	1.000	860	1.000
	2107.52%	5919	2107.52%	1.000	5919	1.000	2107.52%	1.000	5919	1.000
	155.67%	1318	155.67%	1.000	1318	1.000	155.67%	1.000	1318	1.000
ndcc16persp	118.05%	16259	118.05%	1.000	8763	0.542	118.05%	1.000	8767	0.542
	119.98%	7370	119.98%	1.000	16074	2.165	119.98%	1.000	7370	1.000
	118.64%	15438	118.64%	1.000	13389	0.868	118.64%	1.000	6548	0.428
netmod_dol1	39.67%	9671	39.67%	1.000	9682	1.001	40.26%	1.000	8206	0.850
	42.40%	9539	42.40%	1.000	7395	0.778	42.68%	1.000	7010	0.738
	39.62%	12507	39.62%	1.000	11150	0.892	39.90%	1.000	8943	0.717
netmod_dol2	12.04%	1838	12.04%	1.000	1835	0.998	12.04%	1.000	1835	0.998
	12.50%	1743	12.50%	1.000	1741	0.999	12.50%	1.000	1741	0.999
	11.62%	3106	11.62%	1.000	2017	0.660	11.62%	1.000	2020	0.661
netmod_kar1	38.76%	47400	38.76%	1.000	44989	0.949	40.02%	1.000	31604	0.667
	39.64%	46985	39.64%	1.000	46759	0.995	40.79%	1.000	31610	0.673
	40.06%	45850	40.06%	1.000	45623	0.995	41.45%	1.000	31240	0.682
netmod_kar2	38.76%	46404	38.76%	1.000	45573	0.982	40.02%	1.000	31522	0.680
	39.64%	45636	39.64%	1.000	46630	1.022	40.79%	1.000	31532	0.692
	40.06%	47443	40.06%	1.000	46136	0.973	41.45%	1.000	31277	0.660
no7_ar25_1	275.58%	180610	275.56%	1.000	181518	1.005	301.71%	1.000	127626	0.707
	283.11%	177099	283.11%	1.000	176741	0.998	310.49%	1.000	127631	0.721
	286.94%	175487	286.94%	1.000	177535	1.012	301.60%	1.000	125848	0.717
no7_ar2_1	243.38%	187728	243.38%	1.000	188561	1.004	269.92%	1.000	124394	0.663
	252.52%	184735	253.12%	1.000	185739	1.005	281.37%	1.000	124562	0.674
	230.84%	188684	230.97%	1.000	188824	1.001	263.42%	1.000	121204	0.643
no7_ar3_1	316.68%	168662	316.29%	1.000	169065	1.002	335.56%	1.000	125205	0.742
	335.28%	160686	335.00%	1.000	160342	0.998	342.20%	1.000	122870	0.765
	314.11%	166889	314.11%	1.000	166931	1.000	321.90%	1.000	123487	0.740
no7_ar4_1	341.35%	166989	340.79%	1.000	168610	1.010	356.87%	1.000	127986	0.767

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	327.30%	171684	327.52%	1.000	170305	0.992	363.95%	1.000	130837	0.762
	360.27%	163281	361.32%	1.000	161840	0.991	373.21%	1.000	131210	0.804
no7_ar5_1	328.07%	159605	327.03%	1.000	157845	0.989	353.54%	1.000	121345	0.760
	311.42%	158131	311.36%	1.000	157841	0.998	325.62%	1.000	116685	0.738
	311.99%	157965	312.06%	1.000	154970	0.981	325.70%	1.000	117432	0.744
nous1	1771.07%	38406	1771.07%	1.000	38552	1.004	1770.96%	1.000	38471	1.002
	1700.45%	36441	1700.45%	1.000	38771	1.064	1700.45%	1.000	38942	1.068
	1444.47%	39133	1444.47%	1.000	38144	0.975	1444.47%	1.000	39464	1.008
nous2	∞	21172	∞	1.000	21512	1.016	∞	1.000	20515	0.969
	∞	23155	∞	1.000	25642	1.107	∞	1.000	24924	1.076
	∞	15302	∞	1.000	14892	0.973	∞	1.000	10774	0.706
nuclear104	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
nuclear10a	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
	∞	1	∞	1.000	1	1.000	∞	1.000	1	1.000
nuclear10b	≥ 10000%	1	≥ 10000%	1.000	1	1.000	≥ 10000%	1.000	1	1.000
	≥ 10000%	2	≥ 10000%	1.000	2	1.000	≥ 10000%	1.000	2	1.000
	≥ 10000%	1	≥ 10000%	1.000	1	1.000	≥ 10000%	1.000	1	1.000
nuclear14	∞	5351	∞	1.000	5351	1.000	∞	1.000	6049	1.128
	∞	2385	∞	1.000	2385	1.000	∞	1.000	2385	1.000
	∞	5488	∞	1.000	5488	1.000	∞	1.000	5488	1.000
nuclear14a	≥ 10000%	5521	≥ 10000%	1.000	6849	1.236	≥ 10000%	1.000	5521	1.000
	≥ 10000%	2337	≥ 10000%	1.000	2052	0.883	≥ 10000%	1.000	2052	0.883
	≥ 10000%	7245	≥ 10000%	1.000	5661	0.784	≥ 10000%	1.000	7279	1.005
nuclear14b	≥ 10000%	5273	≥ 10000%	1.000	4771	0.907	≥ 10000%	1.000	4771	0.907
	≥ 10000%	5784	≥ 10000%	1.000	4921	0.853	≥ 10000%	1.000	5302	0.918
	≥ 10000%	4152	≥ 10000%	1.000	4152	1.000	≥ 10000%	1.000	4152	1.000
nuclear25	∞	7923	∞	1.000	8170	1.031	∞	1.000	8515	1.074
	∞	8374	∞	1.000	6618	0.793	∞	1.000	6202	0.744
	∞	3229	∞	1.000	3227	0.999	∞	1.000	3255	1.008
nuclear25a	≥ 10000%	5669	≥ 10000%	1.000	6160	1.085	≥ 10000%	1.000	6937	1.220
	≥ 10000%	5378	≥ 10000%	1.000	5042	0.939	≥ 10000%	1.000	5146	0.958

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	≥ 10000%	3894	≥ 10000%	1.000	3896	1.001	≥ 10000%	1.000	3898	1.001
nuclear25b	≥ 10000%	113	≥ 10000%	1.000	115	1.009	≥ 10000%	1.000	113	1.000
	≥ 10000%	2701	≥ 10000%	1.000	2701	1.000	≥ 10000%	1.000	2701	1.000
	≥ 10000%	106	≥ 10000%	1.000	106	1.000	≥ 10000%	1.000	106	1.000
nuclear49	∞	208	∞	1.000	208	1.000	∞	1.000	208	1.000
	∞	186	∞	1.000	187	1.003	∞	1.000	186	1.000
	∞	63	∞	1.000	62	0.994	∞	1.000	62	0.994
nuclear49a	≥ 10000%	920	≥ 10000%	1.000	919	0.999	≥ 10000%	1.000	920	1.000
	≥ 10000%	500	≥ 10000%	1.000	500	1.000	≥ 10000%	1.000	500	1.000
	≥ 10000%	932	≥ 10000%	1.000	932	1.000	≥ 10000%	1.000	932	1.000
nuclear49b	≥ 10000%	1	≥ 10000%	1.000	1	1.000	≥ 10000%	1.000	1	1.000
	≥ 10000%	1	≥ 10000%	1.000	1	1.000	≥ 10000%	1.000	1	1.000
	≥ 10000%	1	≥ 10000%	1.000	1	1.000	≥ 10000%	1.000	1	1.000
nuclearva	∞	41519	∞	1.000	40955	0.986	∞	1.000	41839	1.008
	∞	38248	∞	1.000	39756	1.039	∞	1.000	39743	1.039
	∞	40467	∞	1.000	40971	1.012	∞	1.000	41034	1.014
nuclearvb	∞	36817	∞	1.000	41795	1.135	∞	1.000	41589	1.129
	∞	39340	∞	1.000	39679	1.009	∞	1.000	39887	1.014
	∞	20249	∞	1.000	24227	1.195	∞	1.000	22571	1.114
nuclearvc	∞	21616	∞	1.000	21615	1.000	∞	1.000	21616	1.000
	∞	39695	∞	1.000	40423	1.018	∞	1.000	39804	1.003
	∞	32716	∞	1.000	31946	0.977	∞	1.000	33676	1.029
nuclearvd	∞	22122	∞	1.000	22119	1.000	∞	1.000	22119	1.000
	∞	41044	∞	1.000	40527	0.987	∞	1.000	40502	0.987
	∞	41409	∞	1.000	41776	1.009	∞	1.000	41702	1.007
nuclearve	∞	40641	∞	1.000	41124	1.012	∞	1.000	40837	1.005
	∞	39924	∞	1.000	40392	1.012	∞	1.000	40165	1.006
	∞	40963	∞	1.000	37979	0.927	∞	1.000	41791	1.020
nuclearvf	∞	40810	∞	1.000	40756	0.999	∞	1.000	38734	0.949
	∞	40521	∞	1.000	41020	1.012	∞	1.000	40188	0.992
	∞	40611	∞	1.000	40509	0.997	∞	1.000	40147	0.989
nvs01	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
nvs05	37.95%	5772	38.29%	1.000	3437	0.602	38.30%	1.000	3738	0.654
	43.63%	3330	38.01%	1.000	5462	1.622	43.63%	1.000	1891	0.580
	38.18%	4220	36.76%	1.000	9718	2.273	37.69%	1.000	3770	0.896
nvs06	10.59	7	10.72	1.011	7	1.000	10.77	1.016	7	1.000
	10.60	7	10.64	1.003	7	1.000	10.61	1.001	7	1.000
	10.60	7	10.63	1.003	7	1.000	10.72	1.010	7	1.000
nvs08	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
	0.50	11	0.50	1.000	11	1.000	0.50	1.000	11	1.000
nvs09	1042.12	1605	1045.53	1.003	1605	1.000	1040.97	0.999	1605	1.000
	1042.14	1605	1039.62	0.998	1605	1.000	1040.68	0.999	1605	1.000
	1040.44	1605	1041.32	1.001	1605	1.000	1038.79	0.998	1605	1.000
nvs10	0.50	5	0.50	1.000	5	1.000	0.50	1.000	3	0.981
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	3	0.981
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	3	0.981
nvs11	0.73	7	0.77	1.023	7	1.000	0.73	1.000	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.73	7	0.74	1.006	7	1.000	0.74	1.006	7	1.000
nvs12	0.99	9	1.00	1.005	9	1.000	0.99	1.000	9	1.000
	1.10	9	1.09	0.995	9	1.000	1.11	1.005	9	1.000
	0.93	9	0.92	0.995	9	1.000	0.93	1.000	9	1.000
nvs13	1.50	13	1.49	0.996	13	1.000	1.53	1.012	13	1.000
	1.32	13	1.33	1.004	13	1.000	1.32	1.000	13	1.000
	0.96	13	0.97	1.005	13	1.000	0.96	1.000	13	1.000
nvs15	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
nvs17	3.66	57	3.68	1.004	57	1.000	3.63	0.994	57	1.000
	3.84	57	3.81	0.994	57	1.000	3.73	0.977	57	1.000
	3.53	57	3.53	1.000	57	1.000	3.61	1.018	57	1.000
nvs18	3.07	39	3.01	0.985	39	1.000	2.97	0.975	39	1.000
	2.73	39	2.70	0.992	39	1.000	2.72	0.997	39	1.000
	4.09	39	4.16	1.014	39	1.000	4.08	0.998	39	1.000
nvs19	11.31	131	11.28	0.998	131	1.000	11.27	0.997	131	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	9.64	129	9.60	0.996	129	1.000	9.71	1.007	129	1.000
	10.58	131	10.68	1.009	131	1.000	10.45	0.989	131	1.000
nvs20	31.29	219	31.24	0.998	219	1.000	31.36	1.002	219	1.000
	56.23	244	56.19	0.999	244	1.000	56.53	1.005	244	1.000
	69.44	243	69.93	1.007	243	1.000	69.89	1.006	243	1.000
nvs21	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
	0.50	7	0.50	1.000	7	1.000	0.50	1.000	7	1.000
nvs22	2.10	13	2.07	0.990	13	1.000	1.27	**0.732**	13	1.000
	1.54	13	1.51	0.988	13	1.000	1.23	**0.878**	13	1.000
	2.17	13	2.14	0.991	13	1.000	1.16	**0.681**	13	1.000
nvs23	16.30	127	16.16	0.992	127	1.000	16.04	0.985	127	1.000
	15.90	127	15.76	0.992	127	1.000	15.87	0.998	127	1.000
	24.10	127	24.08	0.999	127	1.000	24.10	1.000	127	1.000
nvs24	18.98	113	18.92	0.997	113	1.000	18.95	0.998	113	1.000
	44.64	117	44.43	0.995	117	1.000	44.54	0.998	117	1.000
	36.01	115	36.39	1.010	115	1.000	36.48	1.013	115	1.000
o7	1153.84%	210012	1153.84%	1.000	209716	0.999	1153.84%	1.000	192650	0.917
	1153.84%	208596	1153.84%	1.000	213016	1.021	1153.84%	1.000	187037	0.897
	1153.84%	213010	1153.84%	1.000	208956	0.981	1153.84%	1.000	187725	0.881
o7_2	1087.07%	194296	1087.07%	1.000	194551	1.001	1087.07%	1.000	168603	0.868
	1179.22%	193692	1181.59%	1.000	192374	0.993	1248.61%	1.000	167241	0.864
	1087.07%	193246	1087.07%	1.000	192781	0.998	1087.07%	1.000	169126	0.875
o7_ar25_1	268.28%	182266	268.33%	1.000	183208	1.005	277.82%	1.000	139675	0.766
	259.50%	182083	259.62%	1.000	181185	0.995	281.31%	1.000	137069	0.753
	261.60%	180964	261.65%	1.000	182557	1.009	278.69%	1.000	139468	0.771
o7_ar2_1	228.29%	191577	228.50%	1.000	191007	0.997	235.07%	1.000	135195	0.706
	217.43%	192577	217.58%	1.000	191042	0.992	232.83%	1.000	134401	0.698
	221.32%	189742	221.56%	1.000	188510	0.994	237.72%	1.000	134232	0.708
o7_ar3_1	299.69%	171875	299.68%	1.000	171214	0.996	320.02%	1.000	133711	0.778
	319.44%	170903	319.90%	1.000	172533	1.010	346.28%	1.000	135217	0.791
	317.18%	169861	317.13%	1.000	171723	1.011	329.91%	1.000	133891	0.788
o7_ar4_1	308.75%	174653	308.41%	1.000	173137	0.991	326.77%	1.000	142214	0.814
	317.03%	166034	317.03%	1.000	176739	1.064	333.23%	1.000	144450	0.870

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	326.35%	172564	326.35%	1.000	158275	0.917	339.62%	1.000	142155	0.824
o7_ar5_1	281.14%	161370	281.08%	1.000	166199	1.030	293.62%	1.000	130065	0.806
	272.18%	164703	272.18%	1.000	165326	1.004	281.37%	1.000	131323	0.797
	271.25%	164114	271.27%	1.000	161517	0.984	284.10%	1.000	131621	0.802
o8_ar4_1	599.68%	151000	599.68%	1.000	150886	0.999	596.33%	1.000	131972	0.874
	624.08%	147906	625.91%	1.000	149934	1.014	631.89%	1.000	132257	0.894
	603.76%	149348	603.76%	1.000	152952	1.024	597.74%	1.000	132795	0.889
o9_ar4_1	1586.70%	132911	1586.70%	1.000	133514	1.005	1586.70%	1.000	123766	0.931
	1586.70%	132569	1586.70%	1.000	136514	1.030	1586.70%	1.000	121090	0.913
	1586.70%	133891	1586.70%	1.000	136291	1.018	1586.70%	1.000	123509	0.923
oaer	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
oil2	3.46%	1000	3.46%	1.000	1000	1.000	3.52%	1.000	956	0.960
	3.51%	762	3.51%	1.000	762	1.000	3.51%	1.000	965	1.235
	3.51%	767	3.51%	1.000	767	1.000	3.52%	1.000	875	1.125
oil	49.66%	973	49.66%	1.000	1126	1.143	49.66%	1.000	957	0.985
	49.06%	1069	49.06%	1.000	1870	1.685	49.06%	1.000	1585	1.441
	49.35%	948	49.35%	1.000	945	0.997	49.35%	1.000	993	1.043
ortez	8.10	127	8.10	1.000	127	1.000	10.06	*1.215*	147	*1.088*
	7.32	111	7.32	1.000	111	1.000	7.39	1.008	109	0.991
	8.81	137	8.82	1.001	137	1.000	10.42	*1.164*	145	1.034
parallel	1361.44	2353	1226.76	**0.901**	1980	**0.848**	1238.89	**0.910**	1980	**0.848**
	1524.37	3311	∞	4.721	49833	14.639	∞	4.721	50033	14.697
	2596.14	7694	1510.27	**0.582**	3098	**0.410**	1518.82	**0.585**	3098	**0.410**
pb302035	737.08%	24	737.08%	1.000	18	0.952	737.08%	1.000	17	0.944
	737.08%	17	737.08%	1.000	28	1.094	737.08%	1.000	26	1.077
	737.08%	14	737.08%	1.000	28	1.123	737.08%	1.000	26	1.105
pb302055	470.96%	21117	471.04%	1.000	20977	0.993	470.96%	1.000	21124	1.000
	471.04%	20933	471.04%	1.000	20947	1.001	471.04%	1.000	20951	1.001
	471.04%	20925	471.04%	1.000	20925	1.000	471.04%	1.000	20923	1.000
pb302075	581.33%	33201	581.35%	1.000	33188	1.000	581.35%	1.000	33171	0.999
	588.94%	32837	588.92%	1.000	32856	1.001	588.99%	1.000	32803	0.999
	581.08%	32611	581.18%	1.000	32539	0.998	581.27%	1.000	32508	0.997

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
pb302095	337.85%	32158	339.73%	1.000	32076	0.997	339.75%	1.000	32044	0.996
	338.21%	32006	339.87%	1.000	31980	0.999	339.69%	1.000	32131	1.004
	339.10%	31871	339.82%	1.000	32023	1.005	339.75%	1.000	32026	1.005
pb351535	342.04%	25940	342.06%	1.000	25858	0.997	342.03%	1.000	25987	1.002
	342.60%	25331	342.60%	1.000	25352	1.001	342.60%	1.000	25367	1.001
	342.28%	24485	342.29%	1.000	24462	0.999	342.26%	1.000	24541	1.002
pb351555	370.89%	11783	370.81%	1.000	11809	1.002	371.00%	1.000	11743	0.997
	380.28%	11737	380.28%	1.000	11754	1.001	380.53%	1.000	11619	0.990
	371.15%	11906	371.19%	1.000	11902	1.000	371.22%	1.000	11890	0.999
pb351575	564.88%	18279	564.88%	1.000	18298	1.001	564.87%	1.000	18303	1.001
	564.79%	18577	564.84%	1.000	18538	0.998	564.79%	1.000	18583	1.000
	564.70%	18620	564.72%	1.000	18598	0.999	564.74%	1.000	18604	0.999
pb351595	610.91%	24727	610.91%	1.000	24741	1.001	610.88%	1.000	24791	1.003
	610.83%	24851	610.90%	1.000	24778	0.997	610.84%	1.000	24825	0.999
	610.83%	24842	610.88%	1.000	24798	0.998	610.82%	1.000	24864	1.001
pooling_epa1	1007.35%	13401	1007.36%	1.000	13560	1.012	1007.36%	1.000	11080	0.828
	1005.82%	13684	1007.36%	1.000	13557	0.991	1008.01%	1.000	11009	0.806
	1005.82%	13837	1005.82%	1.000	13769	0.995	1005.82%	1.000	11271	0.816
pooling_epa2	89.33%	6338	89.33%	1.000	7567	1.191	89.33%	1.000	5772	0.912
	89.33%	7621	89.33%	1.000	7791	1.022	89.33%	1.000	6934	0.911
	89.33%	6562	89.33%	1.000	7593	1.155	89.33%	1.000	6989	1.064
pooling_epa3	143.82%	8440	143.82%	1.000	8439	1.000	143.82%	1.000	8478	1.004
	143.82%	6642	143.82%	1.000	6694	1.008	143.82%	1.000	6357	0.958
	143.82%	9174	143.82%	1.000	9429	1.027	143.82%	1.000	8363	0.913
portfol_buyin	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
portfol_card	0.81	21	0.81	1.000	21	1.000	0.80	0.994	21	1.000
	0.78	21	0.83	1.028	21	1.000	0.80	1.011	21	1.000
	0.82	21	0.80	0.989	21	1.000	0.81	0.995	21	1.000
portfol_classical050_1	3.18%	125203	3.18%	1.000	125382	1.001	3.18%	1.000	78917	0.631
	3.18%	128298	3.18%	1.000	128470	1.001	3.18%	1.000	76531	0.597
	3.18%	125329	3.18%	1.000	124183	0.991	3.18%	1.000	76113	0.608
portfol_classical200_2	13.21%	25085	13.21%	1.000	25101	1.001	13.21%	1.000	23776	0.948

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	13.21%	25128	13.21%	1.000	25112	0.999	13.21%	1.000	23855	0.950
	13.21%	24679	13.21%	1.000	24659	0.999	13.21%	1.000	23353	0.946
portfol_robust050_34	0.10%	17277	0.10%	1.000	17244	0.998	0.10%	1.000	17221	0.997
	0.10%	17789	0.10%	1.000	19402	1.090	0.10%	1.000	17789	1.000
	0.10%	17588	0.10%	1.000	17560	0.998	0.10%	1.000	18734	1.065
portfol_robust100_09	2.79%	4077	2.79%	1.000	3596	0.885	2.79%	1.000	4002	0.982
	2.79%	3348	2.79%	1.000	3466	1.034	2.79%	1.000	3624	1.080
	2.79%	4765	2.79%	1.000	4744	0.996	2.79%	1.000	4312	0.907
portfol_robust200_03	7.18%	1132	7.18%	1.000	1132	1.000	7.18%	1.000	1132	1.000
	7.18%	786	7.18%	1.000	786	1.000	7.18%	1.000	786	1.000
	7.18%	609	7.18%	1.000	609	1.000	7.18%	1.000	609	1.000
portfol_roundlot	2671.43	36018	2803.77	1.050	36478	1.013	1399.47	**0.524**	19102	**0.532**
	2656.16	36756	2658.19	1.001	36756	1.000	1096.74	**0.413**	12145	**0.332**
	2751.33	36096	2766.48	1.006	36096	1.000	1395.76	**0.507**	19202	**0.533**
portfol_shortfall050_68	0.15%	5204	0.15%	1.000	5203	1.000	0.15%	1.000	5204	1.000
	0.15%	11597	0.15%	1.000	10534	0.909	0.15%	1.000	8566	0.741
	0.15%	4587	0.15%	1.000	4574	0.997	0.15%	1.000	4576	0.998
portfol_shortfall100_04	1.49%	1079	1.49%	1.000	1079	1.000	1.49%	1.000	1079	1.000
	1.49%	3464	1.49%	1.000	3555	1.026	1.49%	1.000	3243	0.938
	1.49%	987	1.49%	1.000	987	1.000	1.49%	1.000	987	1.000
portfol_shortfall200_05	2.13%	1006	2.13%	1.000	1006	1.000	2.13%	1.000	1006	1.000
	2.13%	1078	2.13%	1.000	1078	1.000	2.13%	1.000	1078	1.000
	2.13%	1054	2.13%	1.000	1052	0.998	2.13%	1.000	1057	1.003
primary	7664.17%	25647	7664.17%	1.000	25839	1.007	7664.17%	1.000	17451	0.682
	7664.17%	38416	7664.17%	1.000	33577	0.874	7664.17%	1.000	26891	0.701
	7664.17%	39820	7664.17%	1.000	32917	0.827	7664.17%	1.000	18475	0.465
procsel	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
procurement1large	∞	5466	∞	1.000	5837	1.067	∞	1.000	5159	0.945
	∞	6467	∞	1.000	4433	0.690	∞	1.000	4288	0.668
	∞	5281	∞	1.000	4877	0.925	∞	1.000	7001	1.320
procurement1mot	∞	14187	∞	1.000	13810	0.974	∞	1.000	14070	0.992
	∞	13541	∞	1.000	13755	1.016	∞	1.000	14136	1.044

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	13108	∞	1.000	13404	1.022	∞	1.000	13266	1.012
procurement2mot	350.85	3323	347.11	0.989	3323	1.000	348.10	0.992	3323	1.000
	366.47	3475	366.99	1.001	3475	1.000	367.98	1.004	3475	1.000
	358.40	3372	359.23	1.002	3372	1.000	359.81	1.004	3372	1.000
product2	0.56%	33740	0.56%	1.000	34047	1.009	0.57%	1.000	32077	0.951
	0.53%	33614	0.53%	1.000	31738	0.944	0.55%	1.000	32393	0.964
	0.55%	31927	0.55%	1.000	29446	0.923	0.54%	1.000	32319	1.012
product	1.91%	9635	1.91%	1.000	3632	0.383	1.91%	1.000	3617	0.382
	3.30%	3804	3.30%	1.000	3804	1.000	3.30%	1.000	3804	1.000
	2.87%	7988	2.87%	1.000	4797	0.605	2.87%	1.000	3652	0.464
qap	∞	121587	∞	1.000	119267	0.981	∞	1.000	119202	0.980
	≥ 10000%	122814	≥ 10000%	1.000	119314	0.972	≥ 10000%	1.000	119114	0.970
	≥ 10000%	120968	∞	1.000	120196	0.994	∞	1.000	119843	0.991
qapw	∞	1611	∞	1.000	1263	0.797	∞	1.000	1263	0.797
	∞	1200	∞	1.000	1200	1.000	∞	1.000	1200	1.000
	∞	762	∞	1.000	762	1.000	∞	1.000	762	1.000
radar-2000-10-a-6_lat_7	1.70	1	1.70	1.000	1	1.000	1.71	1.004	1	1.000
	1.72	1	1.71	0.996	1	1.000	1.72	1.000	1	1.000
	1.70	1	1.72	1.007	1	1.000	1.73	1.011	1	1.000
radar-3000-10-a-8_lat_7	∞	2	∞	1.000	2	1.000	∞	1.000	2	1.000
	∞	2	∞	1.000	2	1.000	∞	1.000	2	1.000
	∞	2	∞	1.000	2	1.000	∞	1.000	2	1.000
ravempb	48.07	379	48.01	0.999	379	1.000	57.29	*1.188*	377	0.996
	49.51	399	49.14	0.993	399	1.000	45.96	**0.930**	389	0.980
	80.87	405	80.58	0.996	405	1.000	43.66	**0.545**	365	**0.921**
ringpack_10_1	∞	39185	∞	1.000	39669	1.012	∞	1.000	38715	0.988
	∞	39017	∞	1.000	36774	0.943	∞	1.000	38251	0.980
	∞	39228	∞	1.000	39369	1.004	∞	1.000	39015	0.995
ringpack_10_2	∞	30638	∞	1.000	30775	1.004	∞	1.000	30654	1.001
	∞	31541	∞	1.000	31578	1.001	∞	1.000	31149	0.988
	∞	28846	∞	1.000	28582	0.991	∞	1.000	29405	1.019
ringpack_20_1	∞	4264	∞	1.000	4264	1.000	∞	1.000	4264	1.000
	∞	4029	∞	1.000	3961	0.984	∞	1.000	4950	1.223
	∞	5376	∞	1.000	4322	0.808	∞	1.000	4316	0.806

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
ringpack_20_2	∞	4637	∞	1.000	4204	0.909	∞	1.000	4206	0.909
	∞	4343	∞	1.000	4168	0.961	∞	1.000	4077	0.940
	∞	3317	∞	1.000	2579	0.784	∞	1.000	2600	0.790
ringpack_20_3	∞	6370	∞	1.000	6686	1.049	∞	1.000	6390	1.003
	∞	4736	∞	1.000	4736	1.000	∞	1.000	4736	1.000
	∞	6115	∞	1.000	6115	1.000	∞	1.000	6115	1.000
ringpack_30_1	∞	1133	∞	1.000	1133	1.000	∞	1.000	1133	1.000
	∞	854	∞	1.000	854	1.000	∞	1.000	854	1.000
	∞	1643	∞	1.000	1643	1.000	∞	1.000	1643	1.000
ringpack_30_2	∞	407	∞	1.000	407	1.000	∞	1.000	407	1.000
	∞	1302	∞	1.000	1302	1.000	∞	1.000	1302	1.000
	∞	1099	∞	1.000	1099	1.000	∞	1.000	1099	1.000
risk2bpb	892.27	468	893.36	1.001	468	1.000	384.13	**0.431**	229	**0.579**
	157.85	74	157.97	1.001	74	1.000	158.30	1.003	74	1.000
	524.50	339	532.31	1.015	339	1.000	391.34	**0.747**	203	**0.690**
routingdelay_bigm	3.03%	14785	3.03%	1.000	14273	0.966	3.03%	1.000	15321	1.036
	3.03%	11045	3.03%	1.000	11071	1.002	3.03%	1.000	10774	0.976
	3.03%	12487	3.03%	1.000	13871	1.110	3.03%	1.000	13165	1.054
routingdelay_proj	3.03%	3922	3.03%	1.000	4027	1.026	3.03%	1.000	3838	0.979
	25.52%	63597	25.52%	1.000	63222	0.994	25.52%	1.000	76494	1.202
	25.52%	68439	25.52%	1.000	68323	0.998	25.52%	1.000	69270	1.012
	25.52%	62467	25.52%	1.000	61964	0.992	25.52%	1.000	76848	1.230
rsyn0805m02h	111.92%	61272	111.91%	1.000	60974	0.995	111.91%	1.000	61498	1.004
	112.00%	60447	112.00%	1.000	60535	1.001	112.04%	1.000	60739	1.005
	109.87%	58712	109.84%	1.000	59600	1.015	109.85%	1.000	59103	1.007
rsyn0805m02m	117.67%	42391	117.67%	1.000	24023	0.568	116.13%	1.000	59066	1.392
	117.30%	35883	117.30%	1.000	30750	0.857	117.30%	1.000	46847	1.305
	117.61%	47374	117.61%	1.000	48248	1.018	117.61%	1.000	40733	0.860
rsyn0805m03h	121.19%	32502	121.19%	1.000	35760	1.100	121.19%	1.000	45338	1.394
	121.19%	26969	121.19%	1.000	30667	1.137	121.06%	1.000	34521	1.279
	121.30%	29484	121.30%	1.000	29155	0.989	121.30%	1.000	33489	1.135
rsyn0805m03m	71.86%	57682	71.86%	1.000	56399	0.978	71.86%	1.000	52755	0.915
	71.61%	56546	71.61%	1.000	56676	1.002	71.62%	1.000	51762	0.916
	71.70%	57044	71.70%	1.000	57122	1.001	71.70%	1.000	51690	0.906

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
rsyn0805m04h	57.94%	14184	57.94%	1.000	16154	1.138	57.94%	1.000	18258	1.285
	57.88%	18082	57.88%	1.000	18908	1.045	57.88%	1.000	19591	1.083
	57.88%	18395	57.88%	1.000	13236	0.721	57.88%	1.000	17455	0.949
rsyn0805m04m	34.67%	36752	34.70%	1.000	37929	1.032	34.67%	1.000	35421	0.964
	32.51%	37192	32.49%	1.000	34089	0.917	32.49%	1.000	31016	0.834
	33.50%	35782	33.49%	1.000	31625	0.884	33.53%	1.000	31726	0.887
rsyn0805m	7.29%	74788	7.49%	1.000	85528	1.143	7.33%	1.000	77072	1.030
	7.29%	88123	7.38%	1.000	85756	0.973	7.12%	1.000	77656	0.881
	7.32%	86865	6.55%	1.000	86272	0.993	6.90%	1.000	78566	0.905
rsyn0810h	29.48%	47088	29.48%	1.000	59496	1.263	29.48%	1.000	95382	2.023
	29.48%	56119	29.48%	1.000	54251	0.967	29.38%	1.000	87937	1.566
	29.48%	52330	29.48%	1.000	56040	1.071	29.04%	1.000	87518	1.671
rsyn0810m02h	205.63%	55504	205.59%	1.000	56379	1.016	205.57%	1.000	56068	1.010
	212.50%	52576	212.50%	1.000	53275	1.013	212.50%	1.000	53522	1.018
	206.67%	54623	206.50%	1.000	54892	1.005	206.52%	1.000	54252	0.993
rsyn0810m02m	171.93%	84871	171.95%	1.000	84148	0.991	171.94%	1.000	84492	0.996
	212.59%	50368	212.59%	1.000	40391	0.802	212.59%	1.000	42654	0.847
	251.74%	39055	251.74%	1.000	50664	1.296	251.74%	1.000	42229	1.081
rsyn0810m03h	201.97%	32602	201.97%	1.000	33252	1.020	201.97%	1.000	35025	1.074
	202.14%	25144	202.14%	1.000	23052	0.917	202.14%	1.000	22891	0.911
	202.47%	22791	202.47%	1.000	21060	0.924	202.47%	1.000	16903	0.743
rsyn0810m03m	134.58%	50562	134.57%	1.000	51975	1.028	134.58%	1.000	52981	1.048
	130.13%	49794	130.12%	1.000	51703	1.038	130.11%	1.000	52137	1.047
	141.15%	51961	141.15%	1.000	51684	0.995	141.16%	1.000	52536	1.011
rsyn0810m04h	100.04%	17296	100.04%	1.000	14033	0.812	100.04%	1.000	12975	0.752
	99.97%	14104	99.97%	1.000	12619	0.895	99.97%	1.000	11383	0.808
	99.64%	15957	99.64%	1.000	10521	0.661	99.85%	1.000	12222	0.767
rsyn0810m04m	78.50%	24856	78.50%	1.000	26535	1.067	78.50%	1.000	26079	1.049
	86.93%	28896	86.93%	1.000	26846	0.929	86.93%	1.000	23507	0.814
	68.91%	33983	68.72%	1.000	34698	1.021	68.72%	1.000	33604	0.989
rsyn0810m	17.36%	100308	17.36%	1.000	100295	1.000	17.38%	1.000	99987	0.997
	18.35%	112202	18.38%	1.000	112691	1.004	18.46%	1.000	105646	0.942
	16.84%	105703	16.84%	1.000	105742	1.000	16.78%	1.000	114720	1.085
rsyn0815h	57.64%	46902	57.64%	1.000	48504	1.034	57.64%	1.000	58574	1.248

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	58.37%	66249	58.37%	1.000	64777	0.978	58.37%	1.000	71888	1.085
	58.37%	66054	58.37%	1.000	67856	1.027	58.37%	1.000	73060	1.106
rsyn0815m02h	177.02%	39331	177.02%	1.000	36725	0.934	177.02%	1.000	32767	0.834
	177.19%	35169	177.19%	1.000	36703	1.043	177.19%	1.000	31515	0.896
	177.21%	37083	177.21%	1.000	38287	1.032	177.21%	1.000	30853	0.832
rsyn0815m02m	233.80%	45730	233.80%	1.000	44760	0.979	233.80%	1.000	38785	0.848
	230.99%	48654	230.99%	1.000	49573	1.019	230.99%	1.000	35497	0.730
	232.42%	49405	232.42%	1.000	51544	1.043	232.42%	1.000	34245	0.694
rsyn0815m03h	158.68%	20345	158.68%	1.000	20379	1.002	158.68%	1.000	15729	0.774
	156.97%	15343	156.97%	1.000	16513	1.076	156.94%	1.000	11822	0.772
	157.13%	16619	157.13%	1.000	16894	1.016	157.13%	1.000	11043	0.666
rsyn0815m03m	147.80%	35226	147.80%	1.000	34921	0.991	147.80%	1.000	24753	0.704
	128.80%	16794	128.80%	1.000	24015	1.427	128.80%	1.000	17256	1.027
	116.02%	42886	116.03%	1.000	41091	0.958	116.04%	1.000	41920	0.978
rsyn0815m04h	183.68%	12035	183.68%	1.000	12652	1.051	183.68%	1.000	9476	0.789
	182.64%	9942	182.65%	1.000	7513	0.758	182.70%	1.000	5646	0.572
	182.23%	10143	182.23%	1.000	11123	1.096	182.20%	1.000	8754	0.864
rsyn0815m04m	173.36%	28670	173.36%	1.000	28969	1.010	173.36%	1.000	27194	0.949
	166.13%	25763	166.13%	1.000	25493	0.990	166.13%	1.000	21797	0.847
	164.29%	21992	164.29%	1.000	21237	0.966	164.29%	1.000	21857	0.994
rsyn0815m	30.86%	125839	30.90%	1.000	119597	0.950	30.21%	1.000	111692	0.888
	31.18%	129509	30.82%	1.000	128394	0.991	30.87%	1.000	116477	0.899
	30.67%	125693	30.37%	1.000	125402	0.998	30.49%	1.000	119238	0.949
rsyn0820h	119.84%	52200	119.84%	1.000	51728	0.991	119.84%	1.000	46795	0.897
	119.84%	51207	119.84%	1.000	52460	1.024	119.84%	1.000	47922	0.936
	119.84%	51238	119.84%	1.000	51819	1.011	119.84%	1.000	47378	0.925
rsyn0820m02h	265.87%	29425	265.87%	1.000	29358	0.998	265.87%	1.000	22200	0.755
	266.28%	31998	266.28%	1.000	31408	0.982	266.28%	1.000	26091	0.816
	259.62%	18309	259.64%	1.000	19443	1.062	259.64%	1.000	20299	1.108
rsyn0820m02m	383.04%	19091	383.04%	1.000	17031	0.893	383.04%	1.000	42109	2.199
	377.83%	30108	377.83%	1.000	25538	0.849	377.83%	1.000	42834	1.421
	319.68%	63620	320.67%	1.000	63351	0.996	320.71%	1.000	63047	0.991
rsyn0820m03h	218.74%	10479	218.74%	1.000	12804	1.220	218.74%	1.000	10283	0.981
	216.40%	11471	216.40%	1.000	11845	1.032	216.41%	1.000	13648	1.188

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	216.86%	11768	216.86%	1.000	14002	1.188	216.86%	1.000	12768	1.084
rsyn0820m03m	240.87%	25252	240.87%	1.000	27983	1.108	240.87%	1.000	23656	0.937
	223.44%	20341	223.44%	1.000	18253	0.898	223.44%	1.000	22612	1.111
	199.21%	36368	199.31%	1.000	36486	1.003	199.31%	1.000	37321	1.026
rsyn0820m04h	241.20%	5899	241.20%	1.000	5909	1.002	241.20%	1.000	5980	1.014
	241.55%	8016	241.55%	1.000	7610	0.950	241.55%	1.000	7240	0.904
	240.28%	8380	240.28%	1.000	8619	1.028	240.28%	1.000	5272	0.633
rsyn0820m04m	266.15%	16775	266.15%	1.000	16468	0.982	266.15%	1.000	14669	0.875
	274.71%	16419	274.71%	1.000	16188	0.986	274.71%	1.000	14913	0.909
	274.57%	18732	274.57%	1.000	18231	0.973	274.57%	1.000	14383	0.769
rsyn0820m	86.89%	158210	86.95%	1.000	158083	0.999	86.95%	1.000	156397	0.989
	79.93%	156403	79.95%	1.000	155911	0.997	79.96%	1.000	156041	0.998
	89.38%	159231	89.37%	1.000	158500	0.995	89.40%	1.000	146804	0.922
rsyn0830h	149.88%	57378	149.88%	1.000	57531	1.003	149.88%	1.000	49578	0.864
	149.96%	33649	149.96%	1.000	33698	1.001	149.96%	1.000	24462	0.728
	147.57%	41765	147.57%	1.000	43014	1.030	145.52%	1.000	32575	0.780
rsyn0830m02h	243.90%	21507	243.90%	1.000	21200	0.986	243.90%	1.000	17918	0.834
	243.90%	20020	243.90%	1.000	16428	0.821	243.90%	1.000	15801	0.790
	243.99%	17881	243.99%	1.000	24561	1.372	243.99%	1.000	19627	1.097
rsyn0830m02m	505.29%	15698	505.29%	1.000	15691	1.000	505.29%	1.000	33405	2.121
	502.07%	39334	502.07%	1.000	39238	0.998	502.07%	1.000	29143	0.742
	471.86%	54989	471.86%	1.000	54506	0.991	471.86%	1.000	49347	0.898
rsyn0830m03h	168.28%	12786	168.28%	1.000	9210	0.722	168.28%	1.000	9408	0.738
	167.45%	9558	167.45%	1.000	11081	1.158	167.64%	1.000	6891	0.724
	167.66%	11125	167.66%	1.000	9134	0.823	167.66%	1.000	8809	0.794
rsyn0830m03m	354.66%	19077	354.66%	1.000	14379	0.755	354.66%	1.000	14435	0.758
	326.60%	29507	326.60%	1.000	31386	1.063	326.60%	1.000	28098	0.952
	358.95%	19614	358.95%	1.000	22688	1.156	358.95%	1.000	14416	0.736
rsyn0830m04h	138.31%	5273	138.31%	1.000	5573	1.056	138.31%	1.000	5049	0.958
	138.17%	4223	138.17%	1.000	4231	1.002	138.17%	1.000	4175	0.989
	138.06%	4387	138.06%	1.000	4369	0.996	138.06%	1.000	6115	1.385
rsyn0830m04m	301.97%	10937	301.97%	1.000	9931	0.909	301.97%	1.000	7583	0.696
	301.09%	12096	301.09%	1.000	13845	1.143	301.09%	1.000	9869	0.817
	301.03%	9285	301.03%	1.000	15548	1.667	301.03%	1.000	12285	1.320

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Table E.3: Detailed computational results on nonconvex instances of MINLPLIB.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
rsyn0830m	208.88%	123778	208.88%	1.000	123965	1.002	208.88%	1.000	95783	0.774
	234.70%	92854	234.70%	1.000	92854	1.000	220.02%	1.000	95272	1.026
	234.79%	114806	234.79%	1.000	114320	0.996	216.88%	1.000	89671	0.781
rsyn0840h	219.33%	23724	219.33%	1.000	33715	1.419	219.33%	1.000	23096	0.974
	204.58%	31506	204.58%	1.000	30357	0.964	204.58%	1.000	22723	0.722
	199.17%	22221	199.17%	1.000	24097	1.084	201.58%	1.000	18677	0.841
rsyn0840m02h	291.55%	18548	291.55%	1.000	22074	1.189	291.55%	1.000	18958	1.022
	287.89%	13517	287.89%	1.000	9929	0.737	287.89%	1.000	14225	1.052
	291.55%	21343	291.55%	1.000	19475	0.913	291.55%	1.000	17787	0.834
rsyn0840m02m	593.91%	30011	593.91%	1.000	26532	0.884	593.91%	1.000	25867	0.862
	586.49%	30010	586.49%	1.000	25682	0.856	586.49%	1.000	19960	0.666
	589.73%	28361	589.73%	1.000	17854	0.631	589.73%	1.000	25893	0.913
rsyn0840m03h	90.91%	10599	90.91%	1.000	12632	1.190	90.91%	1.000	9332	0.882
	90.91%	5620	90.91%	1.000	6339	1.126	90.91%	1.000	4556	0.814
	90.84%	4409	90.84%	1.000	6277	1.414	90.84%	1.000	5818	1.312
rsyn0840m03m	138.39%	27514	138.39%	1.000	28053	1.020	138.39%	1.000	18497	0.673
	144.44%	16348	144.44%	1.000	10430	0.640	144.44%	1.000	15127	0.926
	143.48%	19441	143.48%	1.000	14242	0.734	143.48%	1.000	11815	0.610
rsyn0840m04h	163.82%	4180	163.82%	1.000	6511	1.545	163.82%	1.000	6491	1.540
	163.65%	3053	163.65%	1.000	3050	0.999	163.65%	1.000	3059	1.002
	163.69%	3414	163.69%	1.000	3403	0.997	163.69%	1.000	6139	1.775
rsyn0840m04m	365.50%	8719	365.50%	1.000	9053	1.038	365.50%	1.000	6998	0.805
	361.03%	9457	361.03%	1.000	13137	1.385	361.03%	1.000	8779	0.929
	362.42%	5481	362.42%	1.000	5496	1.003	362.42%	1.000	7848	1.424
rsyn0840m	391.10%	97763	391.10%	1.000	96510	0.987	391.10%	1.000	67362	0.689
	380.63%	104289	380.63%	1.000	104115	0.998	380.63%	1.000	68625	0.658
	356.83%	100626	356.83%	1.000	101700	1.011	356.83%	1.000	85269	0.848
saa_2	∞	95	∞	1.000	95	1.000	∞	1.000	95	1.000
	∞	92	∞	1.000	92	1.000	∞	1.000	92	1.000
sep1	41.84%	2	41.84%	1.000	2	1.000	41.84%	1.000	2	1.000
	41.84%	3	41.84%	1.000	2	0.990	41.84%	1.000	2	0.990
	41.84%	3	41.84%	1.000	2	0.990	41.84%	1.000	2	0.990
sepasequ_complex	2748.23%	483	1859.08%	1.000	600	1.201	1859.08%	1.000	600	1.201
	2325.77%	472	2325.77%	1.000	592	1.210	2325.77%	1.000	592	1.210

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	2721.34%	896	1904.05%	1.000	668	0.771	1904.05%	1.000	668	0.771
sepasequ_convent	60.22%	792	60.22%	1.000	825	1.037	60.22%	1.000	827	1.039
	60.22%	1704	59.34%	1.000	828	0.514	59.34%	1.000	830	0.516
	352.35%	853	39.12%	1.000	999	1.153	39.12%	1.000	999	1.153
sfacloc1_2_80	∞	32303	∞	1.000	31148	0.964	∞	1.000	29894	0.926
	∞	30637	∞	1.000	31378	1.024	∞	1.000	31640	1.033
	∞	30783	∞	1.000	30701	0.997	∞	1.000	29537	0.960
sfacloc1_2_90	≥ 10000%	48871	≥ 10000%	1.000	48719	0.997	≥ 10000%	1.000	48767	0.998
	≥ 10000%	48979	≥ 10000%	1.000	48908	0.999	≥ 10000%	1.000	48690	0.994
	≥ 10000%	48811	≥ 10000%	1.000	48268	0.989	≥ 10000%	1.000	48386	0.991
sfacloc1_2_95	303.48%	46883	303.48%	1.000	47044	1.003	303.48%	1.000	46667	0.995
	303.21%	46346	303.31%	1.000	46913	1.012	303.31%	1.000	46409	1.001
	303.48%	46631	303.48%	1.000	47466	1.018	303.48%	1.000	46537	0.998
sfacloc1_3_80	∞	16455	∞	1.000	16634	1.011	∞	1.000	16631	1.011
	∞	19606	∞	1.000	17275	0.882	∞	1.000	18583	0.948
	∞	20571	∞	1.000	17295	0.842	∞	1.000	17194	0.837
sfacloc1_3_90	∞	20403	∞	1.000	20036	0.982	∞	1.000	20525	1.006
	∞	19733	∞	1.000	20285	1.028	∞	1.000	20015	1.014
	∞	22572	∞	1.000	21826	0.967	∞	1.000	21851	0.968
sfacloc1_3_95	≥ 10000%	26561	≥ 10000%	1.000	16803	0.634	≥ 10000%	1.000	16863	0.636
	≥ 10000%	25796	≥ 10000%	1.000	30032	1.164	≥ 10000%	1.000	22755	0.883
	≥ 10000%	22421	≥ 10000%	1.000	16533	0.739	≥ 10000%	1.000	25031	1.116
sfacloc1_4_80	∞	25466	∞	1.000	24510	0.963	∞	1.000	25018	0.982
	∞	23621	∞	1.000	22852	0.968	∞	1.000	21888	0.927
	∞	23532	∞	1.000	24191	1.028	∞	1.000	22981	0.977
sfacloc1_4_90	∞	8147	∞	1.000	7359	0.904	∞	1.000	3352	0.419
	∞	5084	∞	1.000	5065	0.996	∞	1.000	5086	1.000
	∞	9606	∞	1.000	8832	0.920	∞	1.000	13351	1.386
sfacloc1_4_95	≥ 10000%	26275	≥ 10000%	1.000	27397	1.043	≥ 10000%	1.000	28134	1.070
	≥ 10000%	25107	≥ 10000%	1.000	23906	0.952	≥ 10000%	1.000	22766	0.907
	≥ 10000%	20423	≥ 10000%	1.000	21651	1.060	≥ 10000%	1.000	18096	0.887
sfacloc2_2_80	≥ 10000%	42222	≥ 10000%	1.000	42212	1.000	≥ 10000%	1.000	42997	1.018
	≥ 10000%	38783	≥ 10000%	1.000	39611	1.021	≥ 10000%	1.000	42635	1.099
	≥ 10000%	42604	≥ 10000%	1.000	42121	0.989	≥ 10000%	1.000	41449	0.973

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
sfacloc2_2_90	753.71%	85958	754.28%	1.000	86368	1.005	756.87%	1.000	85791	0.998
	726.62%	83543	726.62%	1.000	80593	0.965	726.62%	1.000	83902	1.004
	760.45%	84838	760.16%	1.000	85260	1.005	760.66%	1.000	82491	0.972
sfacloc2_2_95	2845.98	28817	2847.26	1.000	28817	1.000	2849.68	1.001	28817	1.000
	2883.73	29005	2880.51	0.999	29005	1.000	2880.04	0.999	29005	1.000
	2785.63	28759	2780.37	0.998	28759	1.000	2786.80	1.000	28759	1.000
sfacloc2_3_80	≥ 10000%	47410	≥ 10000%	1.000	46707	0.985	≥ 10000%	1.000	46703	0.985
	≥ 10000%	48054	≥ 10000%	1.000	48519	1.010	≥ 10000%	1.000	48250	1.004
	≥ 10000%	47329	≥ 10000%	1.000	48177	1.018	≥ 10000%	1.000	48296	1.020
sfacloc2_3_90	2151.66%	99728	2099.63%	1.000	99872	1.001	2099.63%	1.000	99432	0.997
	2020.52%	100923	2090.23%	1.000	100130	0.992	2085.90%	1.000	100948	1.000
	2224.52%	99590	2404.88%	1.000	100548	1.010	2404.88%	1.000	100751	1.012
sfacloc2_3_95	624.39%	108602	556.32%	1.000	113592	1.046	557.09%	1.000	113165	1.042
	531.74%	113893	523.67%	1.000	114127	1.002	523.67%	1.000	114622	1.006
	624.34%	108822	532.55%	1.000	112477	1.034	532.55%	1.000	112148	1.031
sfacloc2_4_80	≥ 10000%	48235	≥ 10000%	1.000	46785	0.970	≥ 10000%	1.000	48005	0.995
	≥ 10000%	49655	≥ 10000%	1.000	47368	0.954	≥ 10000%	1.000	47208	0.951
	≥ 10000%	47346	≥ 10000%	1.000	48153	1.017	≥ 10000%	1.000	48652	1.028
sfacloc2_4_90	≥ 10000%	101058	≥ 10000%	1.000	99760	0.987	≥ 10000%	1.000	99765	0.987
	≥ 10000%	102762	≥ 10000%	1.000	100723	0.980	≥ 10000%	1.000	100781	0.981
	≥ 10000%	102689	≥ 10000%	1.000	101013	0.984	≥ 10000%	1.000	100644	0.980
sfacloc2_4_95	3239.68%	123708	3116.71%	1.000	122740	0.992	3116.71%	1.000	122538	0.991
	3014.74%	124947	3152.03%	1.000	120257	0.962	3152.03%	1.000	120151	0.962
	3037.61%	123219	3003.92%	1.000	120047	0.974	3003.92%	1.000	119446	0.969
sjup2	∞	1080	∞	1.000	1082	1.002	∞	1.000	1082	1.002
	∞	1082	∞	1.000	1082	1.000	∞	1.000	1083	1.001
	∞	2004	∞	1.000	1967	0.982	∞	1.000	1986	0.991
slay04h	22.07	199	22.29	1.010	199	1.000	17.74	**0.812**	195	0.987
	23.19	207	23.02	0.993	207	1.000	18.25	**0.796**	199	0.974
	22.66	199	22.68	1.001	199	1.000	18.06	**0.806**	199	1.000
slay04m	15.35	205	15.32	0.998	205	1.000	2.93	**0.240**	58	**0.518**
	15.47	205	15.46	0.999	205	1.000	3.15	**0.252**	61	**0.528**
	15.58	205	15.85	1.016	205	1.000	2.88	**0.234**	58	**0.518**
slay05m	1.49%	58351	1.49%	1.000	59506	1.020	12.26	**0.002**	257	**0.006**

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1.49%	57142	1.49%	1.000	61241	1.072	13.94	**0.002**	257	**0.006**
	1.49%	59798	1.49%	1.000	41963	0.702	13.25	**0.002**	261	**0.006**
slay06h	1.04%	25349	1.04%	1.000	27826	1.097	0.04%	1.000	23980	0.946
	1.29%	25044	1.04%	1.000	33640	1.342	0.09%	1.000	26118	1.043
	1.04%	39617	1.04%	1.000	24287	0.614	0.08%	1.000	23077	0.584
slay06m	1.04%	42650	1.04%	1.000	41502	0.973	0.03%	1.000	46998	1.102
	1.04%	37935	1.04%	1.000	57215	1.507	6289.59	**0.874**	47371	*1.248*
	1.04%	57372	1.04%	1.000	32097	0.560	36.11	**0.005**	525	**0.011**
slay07h	4.19%	34985	4.19%	1.000	34665	0.991	4.50%	1.000	21800	0.624
	4.19%	35581	4.19%	1.000	35125	0.987	4.19%	1.000	21489	0.605
	4.19%	33859	4.19%	1.000	33873	1.000	4.65%	1.000	21919	0.648
slay07m	3.77%	67407	3.77%	1.000	66775	0.991	332.49	**0.046**	10195	**0.153**
	3.72%	66380	3.74%	1.000	66133	0.996	0.20%	1.000	48478	0.731
	3.74%	67286	3.80%	1.000	66712	0.991	0.58%	1.000	44922	0.668
slay08h	5.21%	24730	5.21%	1.000	25001	1.011	5.21%	1.000	16356	0.663
	5.21%	25355	5.21%	1.000	24711	0.975	5.21%	1.000	16606	0.656
	5.20%	25474	5.20%	1.000	24465	0.961	5.21%	1.000	16459	0.647
slay08m	5.17%	57554	5.17%	1.000	57590	1.001	1298.55	**0.180**	40236	**0.700**
	5.17%	57633	5.17%	1.000	56667	0.983	315.63	**0.044**	6470	**0.114**
	5.17%	59284	5.17%	1.000	57796	0.975	403.10	**0.056**	8879	**0.151**
slay09h	4.54%	19796	4.54%	1.000	17853	0.902	4.54%	1.000	13479	0.682
	4.54%	18756	4.54%	1.000	19485	1.039	4.54%	1.000	13386	0.715
	4.54%	19702	4.54%	1.000	18101	0.919	4.54%	1.000	13475	0.686
slay09m	4.54%	48773	4.54%	1.000	48148	0.987	2.76%	1.000	138643	2.839
	4.54%	47695	4.54%	1.000	48298	1.013	3.13%	1.000	121228	2.539
	4.54%	47866	4.54%	1.000	47661	0.996	2.75%	1.000	126285	2.635
slay10h	8.80%	16402	8.80%	1.000	15190	0.927	8.81%	1.000	11746	0.718
	8.80%	16058	8.80%	1.000	15506	0.966	8.80%	1.000	11203	0.700
	8.80%	14653	8.80%	1.000	14888	1.016	8.80%	1.000	11250	0.769
slay10m	8.80%	44981	8.80%	1.000	44404	0.987	8.36%	1.000	58066	1.290
	8.79%	42042	8.79%	1.000	42656	1.015	8.42%	1.000	62703	1.490
	8.80%	44156	8.79%	1.000	43246	0.979	8.42%	1.000	66266	1.500
smallinvDAXr1b010-011	49.03	211	49.03	1.000	211	1.000	48.98	0.999	211	1.000
	49.21	211	48.43	0.984	211	1.000	48.74	0.991	211	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	49.11	211	48.93	0.996	211	1.000	48.83	0.994	211	1.000
smallinvDAXr1b020-022	57.59	103	57.98	1.007	103	1.000	57.48	0.998	103	1.000
	57.56	103	57.64	1.001	103	1.000	57.97	1.007	103	1.000
	57.66	103	57.88	1.004	103	1.000	57.38	0.995	103	1.000
smallinvDAXr1b050-055	47.33	361	47.50	1.004	361	1.000	46.86	0.990	361	1.000
	47.08	361	47.59	1.011	361	1.000	46.81	0.994	361	1.000
	47.06	361	47.72	1.014	361	1.000	46.70	0.993	361	1.000
smallinvDAXr1b100-110	63.61	779	64.00	1.006	779	1.000	63.36	0.996	779	1.000
	63.77	779	63.80	1.000	779	1.000	63.66	0.998	779	1.000
	63.97	779	63.96	1.000	779	1.000	64.66	1.011	779	1.000
smallinvDAXr1b150-165	421.42	2425	422.91	1.004	2425	1.000	286.10	**0.680**	2379	0.982
	421.06	2425	423.54	1.006	2425	1.000	284.90	**0.677**	2379	0.982
	421.78	2425	421.10	0.998	2425	1.000	285.25	**0.677**	2379	0.982
smallinvDAXr1b200-220	31.34	594	31.58	1.007	594	1.000	31.38	1.001	594	1.000
	31.56	594	31.35	0.994	594	1.000	31.41	0.995	594	1.000
	31.22	594	31.36	1.004	594	1.000	31.27	1.002	594	1.000
smallinvDAXr2b010-011	53.47	213	53.55	1.001	213	1.000	53.74	1.005	213	1.000
	53.68	213	53.47	0.996	213	1.000	53.69	1.000	213	1.000
	53.74	213	53.54	0.996	213	1.000	53.54	0.996	213	1.000
smallinvDAXr2b020-022	22.24	85	22.23	1.000	85	1.000	22.26	1.001	85	1.000
	22.24	85	22.22	0.999	85	1.000	22.31	1.003	85	1.000
	22.36	85	22.29	0.997	85	1.000	22.10	0.989	85	1.000
smallinvDAXr2b050-055	56.41	361	56.02	0.993	361	1.000	55.99	0.993	361	1.000
	56.56	361	56.20	0.994	361	1.000	56.16	0.993	361	1.000
	56.29	361	56.09	0.997	361	1.000	56.31	1.000	361	1.000
smallinvDAXr2b100-110	111.97	787	112.54	1.005	787	1.000	112.88	1.008	787	1.000
	111.64	787	112.68	1.009	787	1.000	111.96	1.003	787	1.000
	112.83	787	111.48	0.988	787	1.000	112.54	0.997	787	1.000
smallinvDAXr2b150-165	455.45	2451	455.93	1.001	2451	1.000	556.70	*1.222*	2489	1.015
	455.51	2451	454.73	0.998	2451	1.000	553.27	*1.214*	2489	1.015
	456.94	2451	455.72	0.997	2451	1.000	554.46	*1.213*	2489	1.015
smallinvDAXr2b200-220	40.95	597	40.75	0.995	597	1.000	41.04	1.002	597	1.000
	41.07	597	40.96	0.997	597	1.000	40.84	0.995	597	1.000
	40.90	597	40.69	0.995	597	1.000	40.93	1.001	597	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
smallinvDAXr3b010-011	18.16	197	17.81	0.982	197	1.000	17.81	0.982	197	1.000
	17.64	197	17.62	0.999	197	1.000	17.80	1.009	197	1.000
	17.64	197	17.91	1.014	197	1.000	17.39	0.987	197	1.000
smallinvDAXr3b020-022	8.94	81	8.90	0.996	81	1.000	8.86	0.992	81	1.000
	8.75	81	8.88	1.013	81	1.000	8.90	1.015	81	1.000
	8.88	81	8.79	0.991	81	1.000	8.75	0.987	81	1.000
smallinvDAXr3b050-055	45.61	357	45.39	0.995	357	1.000	45.76	1.003	357	1.000
	45.58	357	45.26	0.993	357	1.000	45.64	1.001	357	1.000
	45.64	357	45.50	0.997	357	1.000	45.83	1.004	357	1.000
smallinvDAXr3b100-110	98.50	787	97.93	0.994	787	1.000	98.31	0.998	787	1.000
	98.49	787	98.06	0.996	787	1.000	98.21	0.997	787	1.000
	98.13	787	98.17	1.000	787	1.000	99.01	1.009	787	1.000
smallinvDAXr3b150-165	412.60	2427	412.34	0.999	2427	1.000	412.06	0.999	2427	1.000
	412.12	2427	412.22	1.000	2427	1.000	410.41	0.996	2427	1.000
	414.55	2427	411.23	0.992	2427	1.000	411.69	0.993	2427	1.000
smallinvDAXr3b200-220	25.91	598	26.08	1.006	598	1.000	25.84	0.997	598	1.000
	26.11	598	26.03	0.997	598	1.000	26.03	0.997	598	1.000
	26.08	598	26.02	0.998	598	1.000	26.11	1.001	598	1.000
smallinvDAXr4b010-011	27.75	197	27.56	0.993	197	1.000	27.40	0.988	197	1.000
	27.61	197	27.63	1.001	197	1.000	27.58	0.999	197	1.000
	27.33	197	27.57	1.008	197	1.000	27.58	1.009	197	1.000
smallinvDAXr4b020-022	27.26	85	27.29	1.001	85	1.000	27.20	0.998	85	1.000
	27.14	85	27.09	0.998	85	1.000	27.17	1.001	85	1.000
	27.09	85	27.03	0.998	85	1.000	27.38	1.010	85	1.000
smallinvDAXr4b050-055	92.73	379	93.35	1.007	379	1.000	93.22	1.005	379	1.000
	92.90	379	93.24	1.004	379	1.000	93.38	1.005	379	1.000
	93.69	379	93.18	0.995	379	1.000	93.11	0.994	379	1.000
smallinvDAXr4b100-110	61.39	771	61.48	1.001	771	1.000	61.20	0.997	771	1.000
	61.38	771	61.30	0.999	771	1.000	61.07	0.995	771	1.000
	61.00	771	61.30	1.005	771	1.000	61.26	1.004	771	1.000
smallinvDAXr4b150-165	381.70	2413	382.79	1.003	2413	1.000	436.28	*1.143*	2435	1.009
	381.86	2413	380.13	0.995	2413	1.000	435.26	*1.139*	2435	1.009
	380.97	2413	380.97	1.000	2413	1.000	435.98	*1.144*	2435	1.009
smallinvDAXr4b200-220	20.93	594	20.98	1.002	594	1.000	20.96	1.001	594	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	20.89	594	20.88	1.000	594	1.000	20.95	1.003	594	1.000
	20.86	594	20.87	1.000	594	1.000	20.78	0.996	594	1.000
smallinvDAXr5b010-011	43.12	211	43.06	0.999	211	1.000	43.27	1.003	211	1.000
	43.38	211	43.27	0.998	211	1.000	43.05	0.993	211	1.000
	43.24	211	43.38	1.003	211	1.000	43.10	0.997	211	1.000
smallinvDAXr5b020-022	6.01	79	6.08	1.010	79	1.000	6.04	1.004	79	1.000
	5.95	79	6.05	1.014	79	1.000	5.98	1.004	79	1.000
	6.04	79	6.04	1.000	79	1.000	6.09	1.007	79	1.000
smallinvDAXr5b050-055	26.87	357	26.86	1.000	357	1.000	26.85	0.999	357	1.000
	26.91	357	26.73	0.994	357	1.000	26.75	0.994	357	1.000
	26.87	357	27.09	1.008	357	1.000	26.94	1.003	357	1.000
smallinvDAXr5b100-110	57.00	763	57.25	1.004	763	1.000	57.50	1.009	763	1.000
	57.39	763	57.05	0.994	763	1.000	57.66	1.005	763	1.000
	57.36	763	57.08	0.995	763	1.000	57.28	0.999	763	1.000
smallinvDAXr5b150-165	403.86	2431	404.10	1.001	2431	1.000	416.65	1.032	2431	1.000
	404.73	2431	406.05	1.003	2431	1.000	412.93	1.020	2431	1.000
	404.28	2431	403.57	0.998	2431	1.000	412.60	1.021	2431	1.000
smallinvDAXr5b200-220	19.72	598	19.82	1.005	598	1.000	19.70	0.999	598	1.000
	19.55	598	19.88	1.016	598	1.000	19.74	1.009	598	1.000
	19.69	598	19.87	1.009	598	1.000	19.86	1.008	598	1.000
smallinvSNPr1b010-011	∞	577050	∞	1.000	575708	0.998	∞	1.000	577583	1.001
	∞	577062	∞	1.000	579274	1.004	∞	1.000	578031	1.002
	∞	577508	∞	1.000	577327	1.000	∞	1.000	576187	0.998
smallinvSNPr1b020-022	∞	319877	∞	1.000	320018	1.000	∞	1.000	320469	1.002
	∞	319158	∞	1.000	319246	1.000	∞	1.000	320102	1.003
	∞	319852	∞	1.000	321035	1.004	∞	1.000	320647	1.002
smallinvSNPr1b050-055	∞	505273	∞	1.000	504931	0.999	∞	1.000	504542	0.999
	∞	504587	∞	1.000	503944	0.999	∞	1.000	506051	1.003
	∞	504185	∞	1.000	504932	1.001	∞	1.000	504500	1.001
smallinvSNPr1b100-110	∞	544947	∞	1.000	546460	1.003	∞	1.000	546484	1.003
	∞	546972	∞	1.000	545711	0.998	∞	1.000	546133	0.998
	∞	545929	∞	1.000	546255	1.001	∞	1.000	545445	0.999
smallinvSNPr1b150-165	∞	542516	∞	1.000	542693	1.000	∞	1.000	540686	0.997
	∞	542503	∞	1.000	542670	1.000	∞	1.000	542861	1.001

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	540799	∞	1.000	542367	1.003	∞	1.000	540654	1.000
smallinvSNPr1b200-220	∞	544755	∞	1.000	546936	1.004	∞	1.000	545946	1.002
	∞	546492	∞	1.000	547111	1.001	∞	1.000	548290	1.003
	∞	548944	∞	1.000	547627	0.998	∞	1.000	547000	0.996
smallinvSNPr2b010-011	∞	611703	∞	1.000	611570	1.000	∞	1.000	611664	1.000
	∞	611147	∞	1.000	611478	1.001	∞	1.000	610778	0.999
	∞	611572	∞	1.000	610139	0.998	∞	1.000	611723	1.000
smallinvSNPr2b020-022	∞	361152	∞	1.000	362139	1.003	∞	1.000	361826	1.002
	∞	360758	∞	1.000	362295	1.004	∞	1.000	361845	1.003
	∞	362311	∞	1.000	361528	0.998	∞	1.000	362514	1.001
smallinvSNPr2b050-055	∞	519842	∞	1.000	520066	1.000	∞	1.000	520508	1.001
	∞	518760	∞	1.000	520413	1.003	∞	1.000	519934	1.002
	∞	519642	∞	1.000	520633	1.002	∞	1.000	517334	0.996
smallinvSNPr2b100-110	∞	548037	∞	1.000	550248	1.004	∞	1.000	550555	1.005
	∞	549353	∞	1.000	550035	1.001	∞	1.000	549339	1.000
	∞	550808	∞	1.000	551494	1.001	∞	1.000	550691	1.000
smallinvSNPr2b150-165	∞	567294	∞	1.000	566563	0.999	∞	1.000	566997	0.999
	∞	567395	∞	1.000	566773	0.999	∞	1.000	567733	1.001
	∞	567059	∞	1.000	566287	0.999	∞	1.000	566550	0.999
smallinvSNPr2b200-220	∞	569746	∞	1.000	569641	1.000	∞	1.000	572400	1.005
	∞	570666	∞	1.000	572394	1.003	∞	1.000	572354	1.003
	∞	570738	∞	1.000	572861	1.004	∞	1.000	569890	0.999
smallinvSNPr3b010-011	∞	669286	∞	1.000	669576	1.000	∞	1.000	670916	1.002
	∞	669158	∞	1.000	670284	1.002	∞	1.000	670230	1.002
	∞	666793	∞	1.000	669023	1.003	∞	1.000	670240	1.005
smallinvSNPr3b020-022	∞	437270	∞	1.000	435110	0.995	∞	1.000	436016	0.997
	∞	437401	∞	1.000	437178	0.999	∞	1.000	436980	0.999
	∞	437566	∞	1.000	437052	0.999	∞	1.000	437825	1.001
smallinvSNPr3b050-055	∞	554560	∞	1.000	556229	1.003	∞	1.000	555284	1.001
	∞	556991	∞	1.000	556130	0.998	∞	1.000	555784	0.998
	∞	555795	∞	1.000	556664	1.002	∞	1.000	556743	1.002
smallinvSNPr3b100-110	∞	549982	∞	1.000	549796	1.000	∞	1.000	550291	1.001
	∞	550896	∞	1.000	550907	1.000	∞	1.000	552287	1.003
	∞	550536	∞	1.000	550428	1.000	∞	1.000	551782	1.002

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
smallinvSNPr3b150-165	∞	570056	∞	1.000	570553	1.001	∞	1.000	571003	1.002
	∞	571002	∞	1.000	571855	1.001	∞	1.000	570893	1.000
	∞	570965	∞	1.000	571487	1.001	∞	1.000	572077	1.002
smallinvSNPr3b200-220	∞	571023	∞	1.000	572927	1.003	∞	1.000	571128	1.000
	∞	571542	∞	1.000	572316	1.001	∞	1.000	571150	0.999
	∞	572280	∞	1.000	573398	1.002	∞	1.000	572503	1.000
smallinvSNPr4b010-011	∞	756314	∞	1.000	750259	0.992	∞	1.000	749826	0.991
	∞	755900	∞	1.000	747102	0.988	∞	1.000	749058	0.991
	∞	755057	∞	1.000	750858	0.994	∞	1.000	750449	0.994
smallinvSNPr4b020-022	∞	438482	∞	1.000	436903	0.996	∞	1.000	438028	0.999
	∞	437640	∞	1.000	439279	1.004	∞	1.000	438805	1.003
	∞	438991	∞	1.000	438698	0.999	∞	1.000	438049	0.998
smallinvSNPr4b050-055	∞	509344	∞	1.000	509230	1.000	∞	1.000	510399	1.002
	∞	509232	∞	1.000	509734	1.001	∞	1.000	509230	1.000
	∞	509882	∞	1.000	509444	0.999	∞	1.000	510337	1.001
smallinvSNPr4b100-110	∞	518423	∞	1.000	518118	0.999	∞	1.000	518617	1.000
	∞	517950	∞	1.000	518336	1.001	∞	1.000	519046	1.002
	∞	519750	∞	1.000	518908	0.998	∞	1.000	517334	0.995
smallinvSNPr4b150-165	∞	566863	∞	1.000	565758	0.998	∞	1.000	566606	1.000
	∞	567438	∞	1.000	566740	0.999	∞	1.000	568833	1.002
	∞	568612	∞	1.000	566418	0.996	∞	1.000	568490	1.000
smallinvSNPr4b200-220	∞	594638	∞	1.000	595834	1.002	∞	1.000	595568	1.002
	∞	595153	∞	1.000	594780	0.999	∞	1.000	595094	1.000
	∞	594893	∞	1.000	593317	0.997	∞	1.000	594518	0.999
smallinvSNPr5b010-011	3243.66	353377	3258.46	1.005	351904	0.996	3251.52	1.002	351904	0.996
	3251.30	353377	3264.40	1.004	351904	0.996	3259.49	1.003	351904	0.996
	3238.07	353377	3256.57	1.006	351904	0.996	3272.89	1.011	351904	0.996
smallinvSNPr5b020-022	∞	434063	∞	1.000	432964	0.997	∞	1.000	434026	1.000
	∞	433057	∞	1.000	434520	1.003	∞	1.000	432640	0.999
	∞	433614	∞	1.000	432871	0.998	∞	1.000	433500	1.000
smallinvSNPr5b050-055	∞	372750	∞	1.000	373023	1.001	∞	1.000	372201	0.999
	∞	372428	∞	1.000	372932	1.001	∞	1.000	372627	1.001
	∞	374232	∞	1.000	372647	0.996	∞	1.000	372829	0.996
smallinvSNPr5b100-110	∞	474731	∞	1.000	475169	1.001	∞	1.000	475906	1.002

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	474709	∞	1.000	474332	0.999	∞	1.000	475082	1.001
	∞	474587	∞	1.000	476212	1.003	∞	1.000	476198	1.003
smallinvSNPr5b150-165	∞	516741	∞	1.000	517264	1.001	∞	1.000	518647	1.004
	∞	518498	∞	1.000	518416	1.000	∞	1.000	517279	0.998
	∞	518242	∞	1.000	516839	0.997	∞	1.000	512673	0.989
smallinvSNPr5b200-220	∞	565216	∞	1.000	565082	1.000	∞	1.000	565422	1.000
	∞	564472	∞	1.000	564288	1.000	∞	1.000	566021	1.003
	∞	564550	∞	1.000	564972	1.001	∞	1.000	563908	0.999
sonet17v4	∞	4532	∞	1.000	5859	1.286	∞	1.000	5865	1.288
	∞	7578	∞	1.000	8311	1.095	∞	1.000	7722	1.019
	∞	5529	∞	1.000	5772	1.043	∞	1.000	7711	1.388
sonet18v6	∞	1972	∞	1.000	1096	0.577	∞	1.000	1108	0.583
	∞	1769	∞	1.000	1055	0.618	∞	1.000	1065	0.623
	∞	1408	∞	1.000	2075	1.442	∞	1.000	1295	0.925
sonet19v5	∞	863	∞	1.000	706	0.837	∞	1.000	707	0.838
	∞	962	∞	1.000	920	0.960	∞	1.000	920	0.960
	∞	1329	∞	1.000	825	0.647	∞	1.000	825	0.647
sonet20v6	∞	145	∞	1.000	144	0.996	∞	1.000	144	0.996
	∞	124	∞	1.000	124	1.000	∞	1.000	124	1.000
	∞	106	∞	1.000	106	1.000	∞	1.000	106	1.000
sonet21v6	∞	3863	∞	1.000	5013	1.290	∞	1.000	4593	1.184
	∞	3481	∞	1.000	4991	1.422	∞	1.000	5811	1.651
	∞	3961	∞	1.000	5308	1.332	∞	1.000	4562	1.148
sonet22v4	∞	4985	∞	1.000	5428	1.087	∞	1.000	5593	1.120
	∞	7088	∞	1.000	5579	0.790	∞	1.000	6435	0.909
	∞	6321	∞	1.000	5812	0.921	∞	1.000	6406	1.013
sonet22v5	791.84%	89747	791.82%	1.000	90101	1.004	791.84%	1.000	89441	0.997
	792.46%	89633	792.49%	1.000	88802	0.991	792.48%	1.000	88407	0.986
	1003.61%	88457	1003.46%	1.000	88288	0.998	1003.49%	1.000	87831	0.993
sonet23v4	296.02%	63520	295.98%	1.000	64346	1.013	295.99%	1.000	63370	0.998
	344.32%	63268	344.37%	1.000	63652	1.006	344.38%	1.000	63507	1.004
	268.39%	61562	268.37%	1.000	60993	0.991	268.37%	1.000	61024	0.991
sonet23v6	∞	1331	∞	1.000	2148	1.571	∞	1.000	923	0.715
	∞	1189	∞	1.000	1178	0.991	∞	1.000	1178	0.991

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Table E.3: Detailed computational results on nonconvex instances of MINLPLIB.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	1427	∞	1.000	1228	0.870	∞	1.000	1228	0.870
sonet24v2	∞	500	∞	1.000	307	0.678	∞	1.000	308	0.680
	∞	515	∞	1.000	302	0.654	∞	1.000	302	0.654
	∞	504	∞	1.000	365	0.770	∞	1.000	365	0.770
sonet24v5	582.12%	63270	582.12%	1.000	63443	1.003	582.12%	1.000	63146	0.998
	704.10%	63496	704.10%	1.000	63277	0.997	704.10%	1.000	63511	1.000
	704.07%	62681	704.06%	1.000	62665	1.000	704.06%	1.000	62129	0.991
sonet25v5	∞	2856	∞	1.000	3124	1.091	∞	1.000	2926	1.024
	∞	3537	∞	1.000	3565	1.008	∞	1.000	3234	0.917
	∞	3147	∞	1.000	3230	1.026	∞	1.000	3233	1.026
sonet25v6	973.12%	74542	973.15%	1.000	74386	0.998	973.15%	1.000	74230	0.996
	1130.81%	74008	1130.82%	1.000	73798	0.997	1130.82%	1.000	74032	1.000
	972.89%	74251	972.90%	1.000	74272	1.000	972.91%	1.000	73870	0.995
sonetgr17	591.29%	169882	594.45%	1.000	167845	0.988	594.37%	1.000	167266	0.985
	532.90%	168453	600.77%	1.000	166182	0.987	600.80%	1.000	166957	0.991
	558.81%	171534	590.91%	1.000	168023	0.980	591.19%	1.000	166678	0.972
space25	627.46%	39998	627.46%	1.000	49018	1.225	627.46%	1.000	49430	1.235
	627.46%	33651	608.29%	1.000	55948	1.661	608.29%	1.000	56237	1.669
	627.46%	33511	622.40%	1.000	44241	1.319	622.40%	1.000	35074	1.047
space25a	627.46%	45334	627.46%	1.000	42563	0.939	627.46%	1.000	33975	0.750
	627.46%	37443	627.46%	1.000	45564	1.216	627.46%	1.000	36829	0.984
	627.46%	36862	627.46%	1.000	32868	0.892	627.46%	1.000	35698	0.969
space960	164.04%	5284	164.04%	1.000	4596	0.872	164.04%	1.000	4420	0.840
	164.04%	4350	164.04%	1.000	4968	1.139	164.04%	1.000	4305	0.990
	164.03%	4361	164.03%	1.000	4363	1.000	164.03%	1.000	4339	0.995
spectra2	5.17	77	5.18	1.002	77	1.000	5.20	1.005	77	1.000
	5.41	79	5.32	0.986	79	1.000	5.29	0.981	79	1.000
	5.98	79	5.95	0.996	79	1.000	5.94	0.994	79	1.000
sporttournament14	17.21%	12327	17.21%	1.000	11982	0.972	17.21%	1.000	12559	1.019
	17.21%	12640	17.21%	1.000	11700	0.926	17.21%	1.000	11894	0.941
	17.21%	11957	17.21%	1.000	12573	1.051	17.21%	1.000	12592	1.053
spring	0.54	11	0.58	1.026	11	1.000	0.56	1.013	11	1.000
	0.56	11	0.56	1.000	11	1.000	0.58	1.013	11	1.000
	0.58	11	0.60	1.013	11	1.000	0.59	1.006	11	1.000

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Table E.3: Detailed computational results on nonconvex instances of MINLPLIB.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
squfl010-025	571.64	209	572.43	1.001	209	1.000	252.50	**0.443**	179	**0.903**
	526.74	207	526.24	0.999	207	1.000	304.11	**0.578**	181	**0.915**
	505.20	205	504.32	0.998	205	1.000	402.19	**0.797**	191	0.954
squfl010-025persp	11.33	13	11.30	0.998	13	1.000	11.29	0.997	13	1.000
	50.61	15	50.76	1.003	15	1.000	50.74	1.003	15	1.000
	139.03	19	138.72	0.998	19	1.000	138.09	0.993	19	1.000
squfl010-040	1222.33	211	1221.94	1.000	211	1.000	390.26	**0.320**	137	**0.762**
	1114.30	201	1114.20	1.000	201	1.000	780.25	**0.700**	169	**0.894**
	1125.17	199	1128.48	1.003	199	1.000	618.23	**0.550**	163	**0.880**
squfl010-040persp	1.96	1	1.97	1.003	1	1.000	1.96	1.000	1	1.000
	67.21	9	67.20	1.000	9	1.000	67.82	1.009	9	1.000
	5.38	1	5.40	1.003	1	1.000	5.36	0.997	1	1.000
squfl010-080	2843.45	437	2842.06	1.000	437	1.000	1496.84	**0.527**	379	**0.892**
	2936.60	423	2936.19	1.000	423	1.000	1688.43	**0.575**	389	**0.935**
	3632.58	457	3632.92	1.000	457	1.000	1873.52	**0.516**	381	**0.864**
squfl010-080persp	58.00	13	58.34	1.006	13	1.000	58.25	1.004	13	1.000
	173.93	15	174.00	1.000	15	1.000	174.47	1.003	15	1.000
	117.44	15	117.55	1.001	15	1.000	117.64	1.002	15	1.000
squfl015-060	9.40%	906	9.40%	1.000	906	1.000	7.57%	1.000	988	1.082
	9.84%	863	9.77%	1.000	865	1.002	6.25%	1.000	1052	1.196
	9.48%	922	9.48%	1.000	922	1.000	7.02%	1.000	1007	1.083
squfl015-060persp	494.02	25	493.33	0.999	25	1.000	496.08	1.004	25	1.000
	680.83	31	678.71	0.997	31	1.000	682.61	1.003	31	1.000
	1181.21	39	1180.21	0.999	39	1.000	1181.60	1.000	39	1.000
squfl015-080	15.87%	1153	15.87%	1.000	1150	0.998	15.54%	1.000	1150	0.998
	14.00%	1226	13.98%	1.000	1236	1.008	14.59%	1.000	1195	0.977
	15.45%	1168	15.45%	1.000	1168	1.000	15.45%	1.000	1152	0.987
squfl015-080persp	271.41	5	272.02	1.002	5	1.000	271.57	1.001	5	1.000
	1002.19	17	990.37	0.988	17	1.000	1005.48	1.003	17	1.000
	437.09	17	437.52	1.001	17	1.000	436.04	0.998	17	1.000
squfl020-040	5.75%	954	5.75%	1.000	953	0.999	5615.47	**0.780**	1005	1.048
	6.34%	955	6.34%	1.000	955	1.000	5890.79	**0.818**	1019	*1.061*
	9.63%	895	9.63%	1.000	898	1.003	5471.27	**0.760**	947	*1.052*
squfl020-040persp	531.91	15	527.17	0.991	15	1.000	531.64	0.999	15	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	3171.06	33	3162.60	0.997	33	1.000	3161.19	0.997	33	1.000
	785.64	27	779.03	0.992	27	1.000	785.81	1.000	27	1.000
squfl020-050	28.67%	852	28.67%	1.000	852	1.000	23.35%	1.000	1100	1.261
	31.58%	759	31.58%	1.000	761	1.002	27.45%	1.000	902	1.166
	33.81%	719	33.81%	1.000	719	1.000	24.08%	1.000	1032	1.382
squfl020-050persp	4965.68	49	4962.97	0.999	49	1.000	4965.51	1.000	49	1.000
	3012.45	47	3010.42	0.999	47	1.000	3003.77	0.997	47	1.000
	2222.59	35	2220.76	0.999	35	1.000	2223.60	1.000	35	1.000
squfl020-150	20.02%	3574	20.02%	1.000	3574	1.000	19.88%	1.000	3614	1.011
	19.88%	3618	19.88%	1.000	3618	1.000	20.01%	1.000	3578	0.989
	20.26%	3488	20.26%	1.000	3488	1.000	20.61%	1.000	3381	0.970
squfl020-150persp	0.18%	2	0.18%	1.000	2	1.000	0.18%	1.000	2	1.000
	0.13%	34	0.13%	1.000	34	1.000	0.13%	1.000	34	1.000
	5770.80	31	5817.46	1.008	31	1.000	5816.22	1.008	31	1.000
squfl025-025	3.74%	2141	3.74%	1.000	2158	1.008	6044.05	**0.839**	2129	0.995
	5.68%	1957	5.68%	1.000	1961	1.002	5554.82	**0.772**	1939	0.991
	6.47%	1973	6.47%	1.000	2022	1.024	5479.53	**0.761**	1891	0.960
squfl025-025persp	1653.56	63	1652.25	0.999	63	1.000	1653.81	1.000	63	1.000
	1935.39	67	1934.47	1.000	67	1.000	1933.34	0.999	67	1.000
	2674.51	93	2670.95	0.999	93	1.000	2670.08	0.998	93	1.000
squfl025-030	17.21%	1597	17.21%	1.000	1596	0.999	8.30%	1.000	2200	1.355
	17.51%	1588	17.51%	1.000	1589	1.001	3.13%	1.000	2595	1.597
	18.00%	1562	18.00%	1.000	1558	0.998	3.10%	1.000	2520	1.576
squfl025-030persp	1.14%	52	1.14%	1.000	51	0.993	1.14%	1.000	52	1.000
	5446.70	57	5446.55	1.000	57	1.000	5447.98	1.000	57	1.000
	1.14%	45	1.14%	1.000	45	1.000	1.14%	1.000	45	1.000
squfl025-040	42.53%	1122	42.53%	1.000	1122	1.000	40.85%	1.000	1136	1.011
	44.09%	1032	44.09%	1.000	1031	0.999	40.35%	1.000	1124	1.081
	44.21%	1038	44.21%	1.000	1038	1.000	41.95%	1.000	1186	1.130
squfl025-040persp	2077.51	63	2076.35	0.999	63	1.000	2079.27	1.001	63	1.000
	994.06	51	995.67	1.002	51	1.000	992.51	0.998	51	1.000
	1093.80	53	1095.17	1.001	53	1.000	1095.50	1.002	53	1.000
squfl030-100	40.59%	7278	40.59%	1.000	7278	1.000	40.59%	1.000	7278	1.000
	40.49%	7356	40.48%	1.000	7374	1.002	40.49%	1.000	7356	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	40.81%	7176	40.81%	1.000	7176	1.000	40.85%	1.000	7161	0.998
squfl030-100persp	0.00%	7	0.00%	1.000	7	1.000	0.00%	1.000	7	1.000
	0.00%	11	0.00%	1.000	11	1.000	0.00%	1.000	10	0.991
	0.00%	4	0.00%	1.000	4	1.000	0.00%	1.000	4	1.000
squfl030-150	43.33%	6114	43.36%	1.000	6097	0.997	43.39%	1.000	6094	0.997
	43.71%	5907	43.71%	1.000	5921	1.002	43.71%	1.000	5903	0.999
	43.78%	5875	43.78%	1.000	5876	1.000	43.75%	1.000	5884	1.002
squfl030-150persp	5383.06	11	5408.82	1.005	11	1.000	5398.92	1.003	11	1.000
	5893.69	11	5883.35	0.998	11	1.000	5912.57	1.003	11	1.000
	0.23%	11	7172.21	0.996	11	1.000	7196.24	0.999	11	1.000
squfl040-080	57.88%	4148	57.82%	1.000	4163	1.004	57.80%	1.000	4164	1.004
	58.18%	4045	58.18%	1.000	4045	1.000	58.18%	1.000	4045	1.000
	58.18%	4045	58.18%	1.000	4045	1.000	58.18%	1.000	4045	1.000
squfl040-080persp	0.09%	2	0.09%	1.000	2	1.000	0.09%	1.000	2	1.000
	0.09%	2	0.09%	1.000	2	1.000	0.09%	1.000	2	1.000
	0.09%	2	0.09%	1.000	2	1.000	0.09%	1.000	2	1.000
sssd08-04	971.28	72643	966.28	0.995	71308	0.982	967.21	0.996	71308	0.982
	969.83	73449	966.13	0.996	71627	0.975	968.95	0.999	71627	0.975
	995.88	73249	961.07	0.965	71223	0.972	957.12	0.961	71223	0.972
sssd08-04persp	47.59%	180963	48.72%	1.000	176840	0.977	48.70%	1.000	177632	0.982
	48.12%	180859	48.88%	1.000	175900	0.973	48.85%	1.000	177082	0.979
	48.62%	176340	49.17%	1.000	157859	0.895	49.15%	1.000	162371	0.921
sssd12-05	65.98%	318567	66.02%	1.000	316092	0.992	66.02%	1.000	316806	0.994
	65.98%	317511	66.02%	1.000	314646	0.991	66.02%	1.000	314673	0.991
	65.99%	321996	66.02%	1.000	305688	0.949	66.02%	1.000	305921	0.950
sssd12-05persp	147.05%	270151	148.57%	1.000	278321	1.030	148.87%	1.000	277313	1.027
	143.41%	288151	143.89%	1.000	283076	0.982	143.93%	1.000	279936	0.972
	143.55%	283206	149.10%	1.000	277278	0.979	149.33%	1.000	275149	0.972
sssd15-04	77.02%	312859	77.03%	1.000	311958	0.997	77.03%	1.000	312524	0.999
	77.03%	312594	77.03%	1.000	313052	1.001	77.03%	1.000	312036	0.998
	77.06%	310769	77.03%	1.000	311845	1.003	77.03%	1.000	312684	1.006
sssd15-04persp	89.78%	259535	94.60%	1.000	259396	0.999	94.72%	1.000	261065	1.006
	90.92%	258163	86.87%	1.000	256079	0.992	86.72%	1.000	257029	0.996
	101.12%	243630	92.95%	1.000	259238	1.064	92.91%	1.000	258685	1.062

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
sssd15-06	116.70%	242413	116.24%	1.000	231670	0.956	116.24%	1.000	231729	0.956
	116.48%	243705	116.47%	1.000	233623	0.959	116.48%	1.000	233250	0.957
	117.05%	239326	116.64%	1.000	231569	0.968	116.63%	1.000	233111	0.974
sssd15-06persp	324.70%	283364	316.46%	1.000	284315	1.003	316.30%	1.000	285670	1.008
	316.51%	287687	317.22%	1.000	283913	0.987	316.96%	1.000	286139	0.995
	317.89%	287762	316.84%	1.000	285500	0.992	317.05%	1.000	283864	0.986
sssd15-08	131.76%	204780	130.81%	1.000	195789	0.956	130.84%	1.000	195030	0.952
	131.98%	205246	130.98%	1.000	196723	0.958	130.99%	1.000	196639	0.958
	131.65%	204740	130.77%	1.000	195726	0.956	130.75%	1.000	196257	0.959
sssd15-08persp	855.15%	251185	795.46%	1.000	250508	0.997	795.23%	1.000	249987	0.995
	840.49%	249835	791.93%	1.000	248504	0.995	790.55%	1.000	249084	0.997
	839.31%	251752	796.77%	1.000	248791	0.988	794.45%	1.000	250864	0.996
sssd16-07	118.17%	224876	114.91%	1.000	213489	0.949	114.90%	1.000	213362	0.949
	118.40%	223375	114.74%	1.000	215146	0.963	114.76%	1.000	214001	0.958
	118.42%	222029	114.91%	1.000	213139	0.960	114.93%	1.000	204429	0.921
sssd16-07persp	841.67%	262419	905.93%	1.000	264657	1.009	907.83%	1.000	262512	1.000
	842.05%	262171	910.70%	1.000	265402	1.012	910.68%	1.000	263493	1.005
	841.67%	263118	932.02%	1.000	263855	1.003	933.66%	1.000	263432	1.001
sssd18-06	111.97%	240053	108.63%	1.000	233434	0.972	108.67%	1.000	231841	0.966
	112.06%	253132	110.25%	1.000	236751	0.935	110.25%	1.000	237379	0.938
	111.83%	245730	108.48%	1.000	232654	0.947	108.47%	1.000	233181	0.949
sssd18-06persp	375.39%	271981	364.23%	1.000	272037	1.000	364.06%	1.000	273545	1.006
	367.97%	275402	358.44%	1.000	272104	0.988	358.65%	1.000	272275	0.989
	375.63%	275425	367.29%	1.000	271952	0.987	367.54%	1.000	270389	0.982
sssd18-08	186.29%	190840	179.60%	1.000	184984	0.969	179.61%	1.000	185306	0.971
	186.41%	191135	179.65%	1.000	185948	0.973	179.72%	1.000	185415	0.970
	186.36%	189089	179.45%	1.000	182657	0.966	179.44%	1.000	182915	0.967
sssd18-08persp	1505.74%	227683	1411.71%	1.000	223832	0.983	1416.36%	1.000	222328	0.976
	1513.83%	227567	1484.17%	1.000	226171	0.994	1487.85%	1.000	225629	0.991
	1463.01%	227203	1453.02%	1.000	223495	0.984	1449.35%	1.000	225813	0.994
sssd20-04	88.62%	280473	87.60%	1.000	293933	1.048	87.64%	1.000	292485	1.043
	88.03%	288128	86.02%	1.000	286280	0.994	86.02%	1.000	286601	0.995
	86.35%	285469	95.84%	1.000	283079	0.992	95.85%	1.000	282073	0.988
sssd20-04persp	157.07%	262528	147.56%	1.000	272983	1.040	147.56%	1.000	272360	1.037

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	152.15%	267926	147.19%	1.000	274101	1.023	147.17%	1.000	273833	1.022
	150.38%	274176	146.12%	1.000	276279	1.008	146.15%	1.000	274815	1.002
sssd20-08	137.86%	182694	134.70%	1.000	177423	0.971	134.72%	1.000	176967	0.969
	136.20%	181408	134.71%	1.000	175512	0.968	134.69%	1.000	176611	0.974
	137.59%	183988	133.70%	1.000	178878	0.972	133.69%	1.000	178122	0.968
sssd20-08persp	6149.89%	217696	4974.28%	1.000	215275	0.989	4884.30%	1.000	216450	0.994
	6019.60%	217400	4884.30%	1.000	216629	0.996	4884.30%	1.000	217734	1.002
	6242.29%	217290	4898.40%	1.000	214501	0.987	4840.64%	1.000	215516	0.992
sssd22-08	145.79%	172654	143.76%	1.000	167374	0.969	143.78%	1.000	167113	0.968
	145.22%	173555	144.30%	1.000	167741	0.967	144.31%	1.000	166932	0.962
	145.60%	173672	145.20%	1.000	167592	0.965	145.24%	1.000	168192	0.968
sssd22-08persp	7292.17%	211484	7496.56%	1.000	208872	0.988	7478.09%	1.000	210242	0.994
	7300.99%	210267	7496.56%	1.000	208173	0.990	7483.42%	1.000	208675	0.992
	7302.87%	209535	7496.56%	1.000	208367	0.994	7496.56%	1.000	210213	1.003
sssd25-04	120.11%	251111	120.44%	1.000	245270	0.977	120.44%	1.000	244959	0.976
	119.13%	253753	120.32%	1.000	247052	0.974	120.33%	1.000	246169	0.970
	120.13%	248644	119.91%	1.000	246876	0.993	119.91%	1.000	246532	0.992
sssd25-04persp	195.20%	251377	192.45%	1.000	245203	0.975	192.47%	1.000	258403	1.028
	196.18%	256285	194.55%	1.000	257132	1.003	194.50%	1.000	256221	1.000
	197.19%	250317	193.94%	1.000	252695	1.009	193.88%	1.000	251675	1.005
sssd25-08	134.42%	164318	136.04%	1.000	161762	0.984	136.03%	1.000	162174	0.987
	134.11%	165131	135.59%	1.000	163505	0.990	135.64%	1.000	161274	0.977
	134.14%	163408	135.78%	1.000	161475	0.988	135.79%	1.000	160630	0.983
sssd25-08persp	2481.53%	196076	2557.51%	1.000	196462	1.002	2548.08%	1.000	197413	1.007
	2503.03%	196664	2469.46%	1.000	195538	0.994	2465.61%	1.000	197637	1.005
	2608.39%	197570	2840.71%	1.000	196444	0.994	2840.71%	1.000	198129	1.003
st_e14	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
st_e15	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_e27	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
st_e29	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_e31	543.80	3641	544.29	1.001	3641	1.000	542.81	0.998	3641	1.000
	284.71	2001	284.79	1.000	2001	1.000	284.95	1.001	2001	1.000
	1344.54	7941	1342.82	0.999	7941	1.000	1343.42	0.999	7941	1.000
st_e32	5371.23%	19	5371.23%	1.000	18	0.992	5371.23%	1.000	16	0.975
	5371.23%	19	5371.23%	1.000	21	1.017	5371.23%	1.000	21	1.017
	5371.23%	18	5371.23%	1.000	19	1.008	5371.23%	1.000	18	1.000
st_e35	153.52%	4782927	153.52%	1.000	4873969	1.019	153.52%	1.000	5735731	1.199
	147.84%	9919504	147.84%	1.000	9929357	1.001	147.84%	1.000	9942897	1.002
	108.61%	185606	108.61%	1.000	184947	0.996	108.61%	1.000	221203	1.192
st_e36	35.64	693	35.30	0.991	693	1.000	27.60	**0.781**	564	**0.837**
	36.43	690	36.22	0.994	690	1.000	29.91	**0.826**	631	**0.925**
	35.52	693	35.35	0.995	693	1.000	27.84	**0.790**	564	**0.837**
st_e38	0.51	9	0.50	0.993	9	1.000	0.53	1.013	9	1.000
	0.53	9	0.50	0.980	9	1.000	0.54	1.007	9	1.000
	0.52	9	0.52	1.000	9	1.000	0.52	1.000	9	1.000
st_e40	0.53	26	0.53	1.000	26	1.000	0.53	1.000	26	1.000
	0.64	31	0.65	1.006	31	1.000	0.62	0.988	31	1.000
	0.63	25	0.63	1.000	25	1.000	0.62	0.994	25	1.000
st_miqp2	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
st_miqp4	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_miqp5	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
st_test8	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000

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Table E.3: Detailed computational results on nonconvex instances of MINLPLIB.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
st_testgr1	2.49	87	2.47	0.994	87	1.000	0.50	**0.430**	39	**0.743**
	2.52	89	2.57	1.014	89	1.000	0.50	**0.426**	29	**0.683**
	2.76	87	2.80	1.011	87	1.000	0.50	**0.399**	39	**0.743**
st_testgr3	12.72	457	12.73	1.001	457	1.000	1.67	**0.195**	159	**0.465**
	14.73	537	14.64	0.994	537	1.000	1.27	**0.144**	127	**0.356**
	15.46	537	15.44	0.999	537	1.000	1.25	**0.137**	127	**0.356**
stockcycle	1.11%	45983	1.11%	1.000	46311	1.007	1.17%	1.000	45781	0.996
	1.10%	49152	1.10%	1.000	48523	0.987	1.18%	1.000	43336	0.882
	1.10%	49166	1.10%	1.000	48927	0.995	1.17%	1.000	44851	0.912
super3t	46.18%	12638	46.18%	1.000	13273	1.050	46.18%	1.000	12067	0.955
	46.18%	13063	46.18%	1.000	13219	1.012	46.18%	1.000	12128	0.929
	46.18%	12922	46.18%	1.000	13096	1.013	46.18%	1.000	11717	0.907
supplychain	582.42	4241	583.45	1.002	4251	1.002	585.91	1.006	4251	1.002
	709.76	4687	615.45	**0.867**	4624	0.987	614.28	**0.866**	4624	0.987
	519.29	4155	520.53	1.002	4155	1.000	518.68	0.999	4155	1.000
supplychainp1_020306	0.55%	80253	406.78	**0.057**	4890	**0.062**	406.54	**0.057**	4890	**0.062**
	0.53%	78155	555.97	**0.077**	6372	**0.083**	557.87	**0.078**	6372	**0.083**
	0.10%	77912	355.86	**0.050**	4449	**0.058**	354.52	**0.049**	4449	**0.058**
supplychainp1_022020	41.03%	2162	41.03%	1.000	2164	1.001	40.96%	1.000	2171	1.004
	41.18%	2780	41.15%	1.000	2285	0.828	41.27%	1.000	3200	1.146
	39.92%	2351	39.92%	1.000	2352	1.000	39.93%	1.000	2709	1.146
supplychainp1_030510	8.80%	30961	8.80%	1.000	31207	1.008	8.80%	1.000	29278	0.946
	8.80%	29145	6.96%	1.000	20889	0.718	6.96%	1.000	20284	0.697
	8.80%	33007	7.99%	1.000	28054	0.850	7.99%	1.000	27361	0.829
supplychainp1_053050	71.81%	222	71.81%	1.000	222	1.000	71.81%	1.000	222	1.000
	72.28%	210	72.28%	1.000	210	1.000	72.28%	1.000	210	1.000
	72.28%	210	72.28%	1.000	210	1.000	72.28%	1.000	210	1.000
supplychainr1_020306	0.56%	47961	623.92	**0.087**	4416	**0.094**	623.97	**0.087**	4416	**0.094**
	0.57%	53570	1792.26	**0.249**	15436	**0.289**	1795.10	**0.249**	15436	**0.289**
	0.57%	52791	627.97	**0.087**	4529	**0.088**	628.12	**0.087**	4529	**0.088**
supplychainr1_022020	2.30%	3550	2.30%	1.000	3711	1.044	2.30%	1.000	4693	1.313
	2.30%	5459	2.30%	1.000	3805	0.702	2.30%	1.000	3799	0.701
	2.30%	3202	2.30%	1.000	3192	0.997	2.30%	1.000	3423	1.067
supplychainr1_030510	1.52%	23969	0.17%	1.000	25103	1.047	0.43%	1.000	24529	1.023

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	1.62%	25046	1.22%	1.000	21451	0.857	1.29%	1.000	21485	0.858
	1.27%	25254	1.17%	1.000	24051	0.953	1.17%	1.000	22653	0.897
supplychainr1_053050	43.05%	593	43.05%	1.000	593	1.000	43.05%	1.000	593	1.000
	44.43%	628	44.43%	1.000	631	1.004	44.43%	1.000	628	1.000
	43.88%	594	43.88%	1.000	594	1.000	43.88%	1.000	594	1.000
syn05h	59.47%	32	59.47%	1.000	33	1.008	59.47%	1.000	32	1.000
	59.47%	33	59.47%	1.000	35	1.015	59.47%	1.000	34	1.008
	59.47%	32	59.47%	1.000	33	1.008	59.47%	1.000	34	1.015
syn05m02h	57.10%	15	57.10%	1.000	16	1.009	57.10%	1.000	15	1.000
	57.10%	18	57.10%	1.000	18	1.000	57.10%	1.000	18	1.000
	57.10%	19	57.10%	1.000	16	0.975	57.10%	1.000	14	0.958
syn05m02m	1.89	27	1.87	0.993	27	1.000	1.89	1.000	27	1.000
	2.02	27	2.05	1.010	27	1.000	2.03	1.003	27	1.000
	1.74	27	1.77	1.011	27	1.000	1.75	1.004	27	1.000
syn05m03h	61.00%	9	61.00%	1.000	8	0.991	61.00%	1.000	8	0.991
	61.00%	8	61.00%	1.000	9	1.009	61.00%	1.000	8	1.000
	61.00%	9	61.00%	1.000	9	1.000	61.00%	1.000	9	1.000
syn05m03m	4.79	47	4.91	1.021	47	1.000	4.77	0.997	47	1.000
	4.10	47	4.12	1.004	47	1.000	4.22	1.024	47	1.000
	4.40	47	4.30	0.981	47	1.000	4.43	1.006	47	1.000
syn05m04h	58.86%	5	58.86%	1.000	5	1.000	58.86%	1.000	5	1.000
	58.86%	6	58.86%	1.000	7	1.009	58.86%	1.000	7	1.009
	58.86%	9	58.86%	1.000	8	0.991	58.86%	1.000	7	0.982
syn05m04m	10.51	69	10.46	0.996	69	1.000	10.53	1.002	69	1.000
	14.10	73	14.10	1.000	73	1.000	14.15	1.003	73	1.000
	11.77	107	11.87	1.008	107	1.000	11.24	0.958	107	1.000
syn05m	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
syn10h	59.67%	12	59.67%	1.000	13	1.009	59.67%	1.000	12	1.000
	3.26	41	3.24	0.995	41	1.000	3.26	1.000	41	1.000
	59.67%	12	59.67%	1.000	12	1.000	59.67%	1.000	13	1.009
syn10m02h	129.82%	2	129.82%	1.000	3	1.010	129.82%	1.000	3	1.010
	69.74%	72610	69.74%	1.000	70430	0.970	65.19%	1.000	57715	0.795

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	129.82%	4	129.82%	1.000	5	1.010	129.82%	1.000	4	1.000
syn10m02m	81.81	525	82.00	1.002	525	1.000	70.22	**0.860**	521	0.994
	56.20	435	55.88	0.994	435	1.000	55.67	0.991	435	1.000
	59.76	413	59.84	1.001	413	1.000	60.48	1.012	413	1.000
syn10m03h	129.29%	3	129.29%	1.000	2	0.990	129.29%	1.000	2	0.990
	79.01%	49081	79.01%	1.000	49933	1.017	79.01%	1.000	40813	0.832
	79.01%	43822	79.01%	1.000	41994	0.958	79.01%	1.000	36584	0.835
syn10m03m	382.99	1855	379.89	0.992	1855	1.000	381.96	0.997	1855	1.000
	385.88	2395	388.63	1.007	2395	1.000	339.82	**0.881**	2393	0.999
	256.33	1614	258.14	1.007	1614	1.000	255.71	0.998	1614	1.000
syn10m04h	125.04%	2	125.04%	1.000	2	1.000	125.04%	1.000	2	1.000
	70.45%	21329	70.45%	1.000	23955	1.123	70.45%	1.000	18247	0.856
	88.03%	33548	88.03%	1.000	34293	1.022	88.03%	1.000	27403	0.817
syn10m04m	1152.71	4943	1158.39	1.005	4943	1.000	1154.15	1.001	4943	1.000
	878.92	5173	877.65	0.999	5173	1.000	881.85	1.003	5173	1.000
	646.92	3621	673.13	1.040	3559	0.983	674.15	1.042	3559	0.983
syn10m	1.76	31	1.68	0.971	31	1.000	1.72	0.986	31	1.000
	1.80	31	1.78	0.993	31	1.000	1.79	0.996	31	1.000
	1.71	31	1.68	0.989	31	1.000	1.68	0.989	31	1.000
syn15h	266.68	2877	266.21	0.998	2877	1.000	221.39	**0.831**	2453	**0.858**
	39.66	299	39.76	1.002	299	1.000	32.49	**0.824**	237	**0.845**
	101.74	933	101.45	0.997	933	1.000	106.37	1.045	959	1.025
syn15m02h	45.00%	48162	45.00%	1.000	49185	1.021	45.00%	1.000	36435	0.757
	476.16	1843	475.88	0.999	1843	1.000	485.23	1.019	1835	0.996
	45.90%	46423	45.90%	1.000	47300	1.019	45.90%	1.000	41653	0.897
syn15m02m	155.82	1259	147.87	**0.949**	1370	*1.082*	147.97	**0.950**	1370	*1.082*
	167.00	1203	110.68	**0.665**	1039	**0.874**	111.07	**0.667**	1039	**0.874**
	119.46	811	131.83	*1.103*	955	*1.158*	132.07	*1.105*	955	*1.158*
syn15m03h	53.43%	32607	53.43%	1.000	26841	0.824	53.43%	1.000	28248	0.867
	20.55%	22940	20.55%	1.000	20221	0.882	20.55%	1.000	19448	0.848
	30.57%	12319	30.57%	1.000	14073	1.141	31.02%	1.000	9281	0.755
syn15m03m	858.23	4679	970.93	*1.131*	4902	1.047	968.87	*1.129*	4902	1.047
	713.23	3697	714.08	1.001	3697	1.000	714.31	1.002	3697	1.000
	741.63	4351	742.04	1.001	4351	1.000	741.95	1.000	4351	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
syn15m04h	64.23%	22223	64.23%	1.000	20861	0.939	64.23%	1.000	19861	0.894
	42.97%	17111	42.97%	1.000	15889	0.929	42.97%	1.000	12352	0.723
	40.75%	6027	40.75%	1.000	6782	1.123	40.75%	1.000	6428	1.065
syn15m04m	16.51%	53777	8.49%	1.000	39890	0.742	8.51%	1.000	40366	0.751
	25.20%	54646	23.86%	1.000	49925	0.914	23.86%	1.000	40994	0.751
	1.82%	34111	10.37%	1.000	41442	1.214	13.99%	1.000	34216	1.003
syn15m	19.83	107	19.81	0.999	107	1.000	19.95	1.006	107	1.000
	8.18	83	8.12	0.993	83	1.000	8.19	1.001	83	1.000
	6.07	91	6.08	1.001	91	1.000	6.01	0.992	91	1.000
syn20h	215.01%	2	215.01%	1.000	2	1.000	215.01%	1.000	2	1.000
	215.01%	2	215.01%	1.000	2	1.000	215.01%	1.000	2	1.000
	215.01%	3	215.01%	1.000	3	1.000	215.01%	1.000	3	1.000
syn20m02h	132.13%	2	132.13%	1.000	2	1.000	132.13%	1.000	2	1.000
	132.13%	3	132.13%	1.000	3	1.000	132.13%	1.000	3	1.000
	132.13%	3	132.13%	1.000	3	1.000	132.13%	1.000	3	1.000
syn20m02m	25.21%	46568	24.40%	1.000	58132	1.248	24.53%	1.000	56399	1.211
	15.83%	54094	16.75%	1.000	47866	0.885	16.78%	1.000	57457	1.062
	16.97%	62416	17.08%	1.000	61831	0.991	17.13%	1.000	55442	0.888
syn20m03h	90.44%	24955	90.44%	1.000	24660	0.988	90.44%	1.000	18898	0.758
	93.14%	15269	93.14%	1.000	15891	1.040	93.14%	1.000	11328	0.744
	91.75%	19104	91.75%	1.000	16423	0.860	91.75%	1.000	13691	0.718
syn20m03m	80.90%	66560	80.90%	1.000	68254	1.025	80.90%	1.000	52543	0.790
	30.16%	70677	30.14%	1.000	63320	0.896	30.15%	1.000	70433	0.997
	64.88%	40782	64.88%	1.000	52875	1.296	64.88%	1.000	37837	0.928
syn20m04h	93.12%	20201	93.12%	1.000	19885	0.984	93.12%	1.000	16549	0.820
	93.12%	10241	93.12%	1.000	8629	0.844	93.12%	1.000	8916	0.872
	91.27%	9342	91.27%	1.000	13272	1.416	91.27%	1.000	10437	1.116
syn20m04m	100.13%	22207	100.13%	1.000	23669	1.066	100.13%	1.000	26033	1.172
	104.64%	46800	104.64%	1.000	48792	1.042	104.64%	1.000	31621	0.676
	72.47%	39821	80.25%	1.000	25747	0.647	80.25%	1.000	32497	0.817
syn20m	110.02	853	109.90	0.999	853	1.000	110.81	1.007	853	1.000
	110.63	859	110.42	0.998	859	1.000	110.75	1.001	859	1.000
	104.50	873	104.15	0.997	873	1.000	103.55	0.991	873	1.000
syn30h	516.60%	73956	516.60%	1.000	73141	0.989	516.60%	1.000	64960	0.879

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	516.60%	40953	516.60%	1.000	42395	1.035	516.60%	1.000	34796	0.850
	178.29%	34266	178.29%	1.000	40745	1.189	178.29%	1.000	30973	0.904
syn30m02h	429.56%	2	429.56%	1.000	2	1.000	429.56%	1.000	2	1.000
	429.56%	2	429.56%	1.000	2	1.000	429.56%	1.000	2	1.000
	429.56%	2	429.56%	1.000	2	1.000	429.56%	1.000	2	1.000
syn30m02m	312.35%	35970	312.35%	1.000	36229	1.007	312.35%	1.000	46043	1.279
	302.84%	111041	302.84%	1.000	111047	1.000	302.84%	1.000	93019	0.838
	372.81%	19786	372.81%	1.000	20131	1.017	372.81%	1.000	24877	1.256
syn30m03h	247.20%	15301	247.20%	1.000	14193	0.928	247.20%	1.000	12127	0.794
	247.14%	16168	247.14%	1.000	12323	0.764	247.14%	1.000	11298	0.701
	247.14%	14311	247.14%	1.000	16595	1.158	247.14%	1.000	13753	0.961
syn30m03m	296.19%	55619	296.19%	1.000	56661	1.019	296.19%	1.000	49376	0.888
	259.89%	73368	259.89%	1.000	70892	0.966	259.89%	1.000	61251	0.835
	266.37%	72323	266.37%	1.000	74086	1.024	266.37%	1.000	57207	0.791
syn30m04h	253.59%	10009	253.59%	1.000	9045	0.905	253.59%	1.000	10941	1.092
	243.37%	7286	243.37%	1.000	11383	1.555	243.37%	1.000	7318	1.004
	248.15%	9827	248.15%	1.000	7097	0.725	248.15%	1.000	7822	0.798
syn30m04m	272.26%	33881	272.26%	1.000	33402	0.986	272.26%	1.000	24875	0.735
	319.26%	38264	319.26%	1.000	37520	0.981	319.26%	1.000	31171	0.815
	331.35%	29168	331.35%	1.000	11337	0.391	331.35%	1.000	25793	0.885
syn30m	239.75%	144998	239.75%	1.000	130745	0.902	242.73%	1.000	96153	0.663
	383.15%	161509	383.15%	1.000	171431	1.061	337.24%	1.000	177214	1.097
	315.38%	26703	315.38%	1.000	44505	1.664	315.38%	1.000	161972	6.047
syn40h	1053.21%	66575	1053.21%	1.000	65719	0.987	1053.21%	1.000	59391	0.892
	1053.21%	27001	1053.21%	1.000	26318	0.975	1053.21%	1.000	21836	0.809
	1053.21%	31392	1053.21%	1.000	31375	0.999	1053.21%	1.000	24065	0.767
syn40m02h	521.73%	11880	521.73%	1.000	14297	1.202	521.73%	1.000	11121	0.937
	495.97%	11855	495.97%	1.000	16044	1.350	495.97%	1.000	9441	0.798
	507.75%	17426	507.75%	1.000	18471	1.060	507.75%	1.000	13025	0.749
syn40m02m	435.12%	72974	435.12%	1.000	87088	1.193	435.12%	1.000	81253	1.113
	435.23%	87484	435.23%	1.000	87110	0.996	435.23%	1.000	53881	0.616
	438.64%	99698	438.64%	1.000	99464	0.998	438.64%	1.000	88786	0.891
syn40m03h	427.08%	9429	427.08%	1.000	9742	1.033	427.08%	1.000	8531	0.906
	399.87%	7921	399.87%	1.000	9129	1.151	399.87%	1.000	6374	0.807

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	400.41%	3985	400.41%	1.000	7120	1.767	400.41%	1.000	3535	0.890
syn40m03m	557.99%	13978	557.99%	1.000	14089	1.008	557.99%	1.000	21038	1.501
	509.24%	33198	509.24%	1.000	34088	1.027	509.24%	1.000	26345	0.794
	510.81%	48377	510.81%	1.000	46494	0.961	510.81%	1.000	39523	0.817
syn40m04h	433.89%	9227	433.89%	1.000	9505	1.030	433.89%	1.000	7444	0.809
	433.87%	4667	433.87%	1.000	5872	1.253	433.87%	1.000	6419	1.368
	433.87%	3926	433.87%	1.000	3921	0.999	433.87%	1.000	5733	1.449
syn40m04m	411.98%	31266	411.98%	1.000	33130	1.059	411.98%	1.000	27169	0.869
	400.61%	27167	400.61%	1.000	25013	0.921	400.61%	1.000	23991	0.884
	398.62%	21066	398.62%	1.000	21125	1.003	398.62%	1.000	15472	0.736
syn40m	823.95%	25192	823.95%	1.000	33339	1.322	823.95%	1.000	68664	2.719
	856.58%	79239	856.58%	1.000	85721	1.082	856.58%	1.000	104015	1.312
	855.44%	69010	855.44%	1.000	68509	0.993	855.44%	1.000	69962	1.014
synheat	41.12%	26642	41.12%	1.000	25826	0.969	37.87%	1.000	9176	0.347
	41.12%	15477	41.12%	1.000	15477	1.000	38.63%	1.000	11403	0.738
	41.12%	25679	41.12%	1.000	24639	0.960	35.49%	1.000	9301	0.365
synthes1	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
	0.50	5	0.50	1.000	5	1.000	0.50	1.000	5	1.000
synthes2	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
	0.60	9	0.60	1.000	9	1.000	0.60	1.000	9	1.000
	0.50	9	0.50	1.000	9	1.000	0.50	1.000	9	1.000
synthes3	1.19	17	1.17	0.991	17	1.000	1.18	0.995	19	1.017
	1.32	17	1.30	0.991	17	1.000	1.32	1.000	17	1.000
	0.96	17	0.97	1.005	17	1.000	0.89	0.964	17	1.000
tanksize	51.32%	47646	51.32%	1.000	47433	0.996	29.98%	1.000	32255	0.678
	41.03%	49100	41.03%	1.000	59608	1.214	31.72%	1.000	22954	0.469
	50.41%	55507	50.38%	1.000	55054	0.992	30.92%	1.000	33899	0.611
tln12	∞	559584	∞	1.000	557556	0.996	∞	1.000	557830	0.997
	∞	560640	∞	1.000	556917	0.993	∞	1.000	557675	0.995
	∞	556652	∞	1.000	558184	1.003	∞	1.000	558964	1.004
tln2	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000
	0.50	3	0.50	1.000	3	1.000	0.50	1.000	3	1.000

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Table E.3: Detailed computational results on nonconvex instances of MINLPLIB.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
tln4	∞	449728	∞	1.000	444476	0.988	∞	1.000	444613	0.989
	∞	446103	∞	1.000	446659	1.001	∞	1.000	445666	0.999
	∞	453546	∞	1.000	446446	0.984	∞	1.000	446482	0.984
tln5	∞	588007	∞	1.000	588648	1.001	∞	1.000	613299	1.043
	∞	590486	∞	1.000	599734	1.016	∞	1.000	605006	1.025
	∞	595235	∞	1.000	595236	1.000	∞	1.000	609308	1.024
tln6	∞	457421	∞	1.000	452030	0.988	∞	1.000	612200	1.338
	∞	469045	∞	1.000	453529	0.967	∞	1.000	615448	1.312
	∞	458790	∞	1.000	458984	1.000	∞	1.000	616051	1.343
tln7	∞	566576	∞	1.000	568101	1.003	∞	1.000	568815	1.004
	∞	570623	∞	1.000	568771	0.997	∞	1.000	569041	0.997
	∞	572671	∞	1.000	567701	0.991	∞	1.000	570189	0.996
tloss	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
tls12	8959.00%	57090	8688.35%	1.000	53495	0.937	8688.35%	1.000	53371	0.935
	8956.18%	57699	8447.29%	1.000	53792	0.932	8447.29%	1.000	53805	0.933
	8989.73%	57869	8588.86%	1.000	53925	0.932	8588.86%	1.000	53741	0.929
tls2	0.60	37	0.62	1.012	37	1.000	0.57	0.981	37	1.000
	0.62	37	0.58	0.975	37	1.000	0.59	0.981	37	1.000
	0.60	37	0.61	1.006	37	1.000	0.57	0.981	37	1.000
tls4	825.82%	218038	717.60%	1.000	206940	0.949	714.06%	1.000	198613	0.911
	825.82%	214799	711.90%	1.000	204624	0.953	704.07%	1.000	196170	0.913
	834.20%	213831	712.93%	1.000	202994	0.949	706.59%	1.000	193946	0.907
tls5	$\geq$ 10000%	149543	$\geq$ 10000%	1.000	145537	0.973	$\geq$ 10000%	1.000	137873	0.922
	$\geq$ 10000%	149510	$\geq$ 10000%	1.000	140982	0.943	$\geq$ 10000%	1.000	134053	0.897
	$\geq$ 10000%	150758	$\geq$ 10000%	1.000	139935	0.928	$\geq$ 10000%	1.000	133831	0.888
tls6	4417.85%	110376	4304.66%	1.000	116245	1.053	4285.43%	1.000	116619	1.057
	4421.96%	107843	4281.70%	1.000	120948	1.121	4321.09%	1.000	114680	1.063
	4421.11%	109803	4237.90%	1.000	115342	1.050	4298.87%	1.000	115038	1.048
tls7	5650.52%	114327	5643.85%	1.000	103278	0.903	5646.63%	1.000	95789	0.838
	5650.52%	116943	5645.43%	1.000	99709	0.853	5644.18%	1.000	94710	0.810
	5650.37%	119941	5644.94%	1.000	102736	0.857	5645.82%	1.000	95484	0.796
tltr	0.84	89	1.08	*1.130*	101	*1.063*	1.10	*1.141*	101	*1.063*

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	3.44	309	2.64	**0.820**	202	**0.738**	2.65	**0.822**	202	**0.738**
	0.75	69	0.76	1.006	71	1.012	0.78	1.017	71	1.012
topopt-cantilever_60x40_50	∞	15601	∞	1.000	15509	0.994	∞	1.000	15268	0.979
	∞	16365	∞	1.000	15271	0.934	∞	1.000	16340	0.998
	∞	15915	∞	1.000	15416	0.969	∞	1.000	16402	1.030
topopt-mbb_60x40_50	∞	15595	∞	1.000	15095	0.968	∞	1.000	15692	1.006
	∞	16482	∞	1.000	16416	0.996	∞	1.000	16419	0.996
	∞	16329	∞	1.000	16387	1.004	∞	1.000	16459	1.008
topopt-zhou-rozvany_75	∞	1681	∞	1.000	1681	1.000	∞	1.000	1681	1.000
	∞	1426	∞	1.000	1426	1.000	∞	1.000	1426	1.000
	∞	1530	∞	1.000	1530	1.000	∞	1.000	1530	1.000
toroidal2g20_5555	∞	63201	∞	1.000	63306	1.002	∞	1.000	63447	1.004
	∞	63568	∞	1.000	63327	0.996	∞	1.000	63607	1.001
	∞	63644	∞	1.000	63857	1.003	∞	1.000	63636	1.000
toroidal3g7_6666	∞	74921	∞	1.000	74756	0.998	∞	1.000	74600	0.996
	∞	74931	∞	1.000	75058	1.002	∞	1.000	75076	1.002
	∞	75080	∞	1.000	75041	0.999	∞	1.000	74976	0.999
transswitch0009r	345.57%	27669	345.57%	1.000	27056	0.978	345.57%	1.000	26608	0.962
	345.57%	22774	345.57%	1.000	22858	1.004	345.57%	1.000	30125	1.321
	345.57%	31875	345.57%	1.000	32248	1.012	345.57%	1.000	31770	0.997
transswitch0014r	≥ 10000%	30425	≥ 10000%	1.000	27439	0.902	≥ 10000%	1.000	29279	0.962
	≥ 10000%	29727	≥ 10000%	1.000	30214	1.016	≥ 10000%	1.000	30419	1.023
	≥ 10000%	31842	≥ 10000%	1.000	33325	1.046	≥ 10000%	1.000	32441	1.019
transswitch0030r	≥ 10000%	9275	≥ 10000%	1.000	9135	0.985	≥ 10000%	1.000	8399	0.907
	≥ 10000%	8227	≥ 10000%	1.000	9307	1.130	≥ 10000%	1.000	6400	0.781
	≥ 10000%	7207	≥ 10000%	1.000	8115	1.124	≥ 10000%	1.000	9169	1.269
transswitch0039r	≥ 10000%	11546	≥ 10000%	1.000	8440	0.733	≥ 10000%	1.000	11855	1.027
	≥ 10000%	11556	≥ 10000%	1.000	10605	0.918	≥ 10000%	1.000	12392	1.072
	≥ 10000%	10529	≥ 10000%	1.000	11208	1.064	≥ 10000%	1.000	12172	1.155
transswitch0057r	∞	8246	∞	1.000	6445	0.784	∞	1.000	7808	0.948
	∞	6629	∞	1.000	7780	1.171	∞	1.000	8106	1.219
	∞	6569	∞	1.000	6266	0.955	∞	1.000	7651	1.162
transswitch0118r	∞	2501	∞	1.000	2501	1.000	∞	1.000	2505	1.002
	∞	2784	∞	1.000	2783	1.000	∞	1.000	3370	1.203

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	2526	∞	1.000	3411	1.337	∞	1.000	2522	0.998
transswitch0300r	∞	1025	∞	1.000	1027	1.002	∞	1.000	1298	1.243
	∞	1082	∞	1.000	1082	1.000	∞	1.000	1082	1.000
	∞	1103	∞	1.000	1103	1.000	∞	1.000	1103	1.000
transswitch2383wpr	∞	144	∞	1.000	144	1.000	∞	1.000	144	1.000
	∞	136	∞	1.000	135	0.996	∞	1.000	136	1.000
transswitch2736spr	∞	73	∞	1.000	73	1.000	∞	1.000	73	1.000
	∞	75	∞	1.000	75	1.000	∞	1.000	75	1.000
	∞	73	∞	1.000	73	1.000	∞	1.000	73	1.000
tspn05	7.56%	49424	7.55%	1.000	47639	0.964	7.52%	1.000	33476	0.678
	7.41%	47860	7.41%	1.000	40705	0.851	7.73%	1.000	34842	0.729
	7.61%	47725	7.62%	1.000	47039	0.986	7.55%	1.000	34762	0.729
tspn08	179.62%	6	179.62%	1.000	5	0.991	179.62%	1.000	4	0.981
	179.62%	7	179.62%	1.000	7	1.000	179.62%	1.000	7	1.000
	319.10	1	319.40	1.001	1	1.000	319.48	1.001	1	1.000
tspn10	238.47%	22450	238.47%	1.000	22131	0.986	238.47%	1.000	15673	0.699
	232.50%	21487	252.31%	1.000	22188	1.032	229.30%	1.000	18245	0.850
	217.43%	16041	217.43%	1.000	21709	1.351	217.43%	1.000	20246	1.261
tspn12	$\geq$ 10000%	22453	$\geq$ 10000%	1.000	23695	1.055	$\geq$ 10000%	1.000	23920	1.065
	$\geq$ 10000%	24063	$\geq$ 10000%	1.000	24331	1.011	$\geq$ 10000%	1.000	23232	0.966
	$\geq$ 10000%	21573	$\geq$ 10000%	1.000	24011	1.112	$\geq$ 10000%	1.000	22720	1.053
tspn15	322.58%	12273	322.58%	1.000	14256	1.160	324.36%	1.000	12810	1.043
	305.35%	15173	305.35%	1.000	14280	0.942	305.35%	1.000	14550	0.959
	314.17%	14823	314.86%	1.000	14604	0.985	314.86%	1.000	13651	0.921
unitcommit1	0.34%	7930	0.34%	1.000	3670	0.469	0.39%	1.000	3627	0.464
	0.44%	4704	0.48%	1.000	4753	1.010	0.48%	1.000	4319	0.920
	0.47%	8921	0.47%	1.000	8162	0.916	0.50%	1.000	3582	0.408
unitcommit2	53.20%	6821	53.20%	1.000	4748	0.700	53.20%	1.000	4366	0.645
	3.01	1	3.01	1.000	1	1.000	3.00	0.998	1	1.000
	116.73%	3190	116.73%	1.000	3190	1.000	61.02%	1.000	3558	1.112
unitcommit_200_0_5_mod_7	427.99	1	427.11	0.998	1	1.000	429.21	1.003	1	1.000
	1208.85	7	1206.12	0.998	7	1.000	1207.27	0.999	7	1.000
	421.13	1	421.35	1.001	1	1.000	421.51	1.001	1	1.000
unitcommit_200_100_1_mod_8	∞	30	∞	1.000	30	1.000	∞	1.000	30	1.000

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	22	∞	1.000	22	1.000	∞	1.000	22	1.000
	∞	19	∞	1.000	19	1.000	∞	1.000	19	1.000
unitcommit_200_100_2_mod_7	∞	20	∞	1.000	20	1.000	∞	1.000	20	1.000
	∞	2	∞	1.000	2	1.000	∞	1.000	2	1.000
	∞	6	∞	1.000	6	1.000	∞	1.000	6	1.000
unitcommit_200_100_2_mod_8	∞	17	∞	1.000	17	1.000	∞	1.000	17	1.000
	∞	14	∞	1.000	14	1.000	∞	1.000	14	1.000
	∞	13	∞	1.000	13	1.000	∞	1.000	13	1.000
unitcommit_50_20_2_mod_8	∞	1051	∞	1.000	1012	0.966	∞	1.000	1196	1.126
	∞	560	∞	1.000	894	1.506	∞	1.000	855	1.447
	∞	677	∞	1.000	865	1.242	∞	1.000	867	1.245
uselinear	∞	17	∞	1.000	17	1.000	∞	1.000	17	1.000
	∞	18	∞	1.000	18	1.000	∞	1.000	18	1.000
	∞	17	∞	1.000	17	1.000	∞	1.000	17	1.000
util	261.32	2512	260.99	0.999	2512	1.000	262.74	1.005	2512	1.000
	254.42	2759	253.88	0.998	2759	1.000	254.50	1.000	2759	1.000
	580.65	2393	585.86	1.009	2393	1.000	587.46	1.012	2393	1.000
wager	∞	1607	∞	1.000	2270	1.388	∞	1.000	2270	1.388
	∞	4891	∞	1.000	4149	0.851	∞	1.000	4147	0.851
	∞	2899	∞	1.000	2652	0.918	∞	1.000	2649	0.917
waste	130.96%	11906	130.96%	1.000	12661	1.063	130.96%	1.000	13038	1.094
	130.83%	12259	130.84%	1.000	12962	1.057	130.83%	1.000	12987	1.059
	131.07%	12812	131.05%	1.000	12279	0.959	131.05%	1.000	12354	0.965
wastepaper3	871.16	14187	867.01	0.995	14187	1.000	820.54	**0.942**	14193	1.000
	827.86	14143	828.92	1.001	14143	1.000	816.79	0.987	14147	1.000
	855.81	14249	857.18	1.002	14249	1.000	834.02	0.975	14239	0.999
wastepaper4	∞	173563	∞	1.000	173233	0.998	∞	1.000	167408	0.965
	∞	165512	∞	1.000	165686	1.001	∞	1.000	177032	1.070
	∞	165490	∞	1.000	165764	1.002	∞	1.000	174525	1.055
wastepaper5	∞	207495	∞	1.000	207377	0.999	∞	1.000	206663	0.996
	∞	201994	∞	1.000	202504	1.003	∞	1.000	208232	1.031
	∞	201882	∞	1.000	202292	1.002	∞	1.000	210263	1.041
wastepaper6	∞	212324	∞	1.000	211794	0.998	∞	1.000	211952	0.998
	∞	210882	∞	1.000	209578	0.994	∞	1.000	210490	0.998

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	∞	212696	∞	1.000	212578	0.999	∞	1.000	211984	0.997
water3	422.14%	40682	422.14%	1.000	28464	0.700	422.14%	1.000	28464	0.700
	422.60%	38127	422.14%	1.000	40091	1.051	422.60%	1.000	40964	1.074
	426.63%	26889	426.63%	1.000	26889	1.000	426.63%	1.000	26889	1.000
water4	213.86%	55308	213.45%	1.000	54726	0.989	213.45%	1.000	54728	0.990
	211.21%	53575	210.66%	1.000	54304	1.014	210.66%	1.000	53743	1.003
	212.33%	54009	212.63%	1.000	51613	0.956	212.46%	1.000	53121	0.984
watercontamination0202	7.65	29	7.55	0.988	29	1.000	8.20	*1.064*	29	1.000
	9.17	33	9.12	0.995	33	1.000	10.46	*1.127*	35	1.015
	8.14	31	8.10	0.996	31	1.000	8.16	1.002	29	0.985
watercontamination0202r	0.93	31	0.93	1.000	31	1.000	0.93	1.000	31	1.000
	0.96	31	0.95	0.995	31	1.000	0.94	0.990	31	1.000
	0.95	31	0.96	1.005	31	1.000	0.95	1.000	31	1.000
watercontamination0303	162.49	275	161.87	0.996	275	1.000	113.61	**0.701**	279	1.011
	178.36	275	178.87	1.003	275	1.000	109.59	**0.617**	275	1.000
	180.47	275	180.57	1.001	275	1.000	102.33	**0.569**	279	1.011
watercontamination0303r	37.68	263	37.65	0.999	263	1.000	37.57	0.997	263	1.000
	38.31	267	38.24	0.998	267	1.000	38.38	1.002	267	1.000
	21.11	285	21.09	0.999	285	1.000	21.25	1.006	285	1.000
waterful2	238.47%	10573	238.47%	1.000	14717	1.388	238.48%	1.000	12929	1.221
	238.37%	16687	238.37%	1.000	17459	1.046	238.36%	1.000	9871	0.594
	238.06%	12714	238.06%	1.000	13423	1.055	238.13%	1.000	13274	1.044
waternd1	4481.17	24097	4483.90	1.001	24097	1.000	4479.82	1.000	24097	1.000
	4514.23	23868	4503.68	0.998	23868	1.000	4518.44	1.001	23868	1.000
	4299.18	22879	4291.07	0.998	22879	1.000	4290.31	0.998	22879	1.000
waternd2	46.44%	13508	46.44%	1.000	13898	1.029	46.44%	1.000	13373	0.990
	46.44%	12134	46.44%	1.000	12552	1.034	46.44%	1.000	12448	1.026
	46.44%	10988	46.44%	1.000	11637	1.059	46.44%	1.000	11042	1.005
waternd_blacksburg	12.07%	54166	12.01%	1.000	52507	0.969	12.01%	1.000	52516	0.970
	12.06%	52253	12.06%	1.000	55706	1.066	12.06%	1.000	55338	1.059
	12.06%	52465	12.07%	1.000	62979	1.200	12.07%	1.000	64108	1.221
waternd_fossiron	∞	27615	∞	1.000	27583	0.999	∞	1.000	24147	0.875
	∞	27483	∞	1.000	26478	0.964	∞	1.000	26344	0.959
	∞	26394	∞	1.000	27785	1.053	∞	1.000	25747	0.976

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
waternd_fosspoly0	∞	29923	∞	1.000	31001	1.036	∞	1.000	29535	0.987
	∞	31507	∞	1.000	29942	0.950	∞	1.000	30124	0.956
	∞	31583	∞	1.000	29236	0.926	∞	1.000	28813	0.913
waternd_fosspoly1	13.24%	8170	13.24%	1.000	9954	1.216	13.24%	1.000	13252	1.615
	13.24%	7320	13.24%	1.000	8199	1.118	13.24%	1.000	9237	1.258
	13.24%	7599	13.24%	1.000	10763	1.411	13.24%	1.000	7376	0.971
waternd_hanoi	18.66%	53732	18.66%	1.000	55763	1.038	18.66%	1.000	48594	0.905
	20.73%	50452	20.73%	1.000	50665	1.004	20.73%	1.000	39253	0.778
	20.73%	52472	20.73%	1.000	54693	1.042	20.73%	1.000	42582	0.812
waternd_modena	24.47%	2830	24.47%	1.000	2462	0.874	24.47%	1.000	2451	0.871
	24.47%	2400	24.47%	1.000	4684	1.914	24.47%	1.000	2677	1.111
	24.47%	2464	24.47%	1.000	3575	1.433	24.47%	1.000	2467	1.001
waternd_pescara	⩾ 10000%	7988	⩾ 10000%	1.000	7700	0.964	⩾ 10000%	1.000	8013	1.003
	⩾ 10000%	9320	⩾ 10000%	1.000	7940	0.854	⩾ 10000%	1.000	8314	0.893
	⩾ 10000%	9069	⩾ 10000%	1.000	10244	1.128	⩾ 10000%	1.000	8302	0.916
waternd_shamir	3097.46	112327	2117.59	**0.684**	84489	**0.752**	1480.94	**0.478**	61621	**0.549**
	3039.89	111331	2072.45	**0.682**	75533	**0.679**	1397.74	**0.460**	57286	**0.515**
	2837.48	106807	2215.00	**0.781**	86154	**0.807**	1262.94	**0.445**	53984	**0.506**
waterno1_01	2.81	21	2.81	1.000	21	1.000	3.02	*1.055*	23	1.017
	3.68	25	3.73	1.011	25	1.000	3.77	1.019	25	1.000
	3.28	23	3.30	1.005	23	1.000	3.32	1.009	23	1.000
waterno1_02	304.07	879	307.73	1.012	885	1.006	287.98	**0.947**	889	1.010
	306.42	885	307.61	1.004	885	1.000	272.30	**0.889**	875	0.990
	292.20	881	300.13	1.027	869	0.988	270.56	**0.926**	863	0.982
waterno1_03	5.42%	16994	5.42%	1.000	12831	0.756	5.85%	1.000	12975	0.765
	5.87%	18728	8.84%	1.000	20186	1.077	5.84%	1.000	13098	0.701
	5.87%	16092	5.84%	1.000	15776	0.980	5.89%	1.000	13494	0.840
waterno1_04	12.08%	17268	12.13%	1.000	13033	0.756	12.12%	1.000	13189	0.765
	11.94%	13401	11.88%	1.000	13441	1.003	11.94%	1.000	13309	0.993
	11.98%	12817	11.96%	1.000	12722	0.993	11.90%	1.000	12902	1.007
waterno1_06	22.60%	10600	21.94%	1.000	12247	1.154	22.60%	1.000	10603	1.000
	23.80%	11740	24.34%	1.000	9351	0.798	24.52%	1.000	10278	0.877
	24.41%	9814	24.45%	1.000	13578	1.380	24.45%	1.000	9848	1.003
waterno1_09	25.66%	10579	25.66%	1.000	14249	1.344	25.66%	1.000	10778	1.019

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Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	25.66%	13923	25.66%	1.000	14361	1.031	25.66%	1.000	10901	0.784
	25.66%	14793	25.66%	1.000	15115	1.022	25.66%	1.000	12018	0.814
waterno1_12	25.64%	10430	25.64%	1.000	10892	1.044	25.64%	1.000	9249	0.888
	25.64%	11447	25.64%	1.000	11481	1.003	25.64%	1.000	10707	0.936
	25.64%	12600	25.64%	1.000	9935	0.790	25.64%	1.000	9642	0.767
waterno1_18	26.19%	6540	26.19%	1.000	5273	0.809	26.19%	1.000	7292	1.113
	26.19%	6172	26.19%	1.000	5074	0.825	26.19%	1.000	5308	0.862
	26.19%	6441	26.19%	1.000	5580	0.868	26.19%	1.000	5499	0.856
waterno1_24	27.16%	3868	27.16%	1.000	3917	1.012	27.16%	1.000	3936	1.017
	27.16%	3828	27.16%	1.000	3800	0.993	27.16%	1.000	5990	1.550
	27.16%	3751	27.16%	1.000	3730	0.995	27.16%	1.000	5856	1.547
waterno2_01	7.71	27	7.65	0.993	27	1.000	7.70	0.999	27	1.000
	3.85	23	3.78	0.986	23	1.000	3.79	0.988	23	1.000
	5.01	25	4.98	0.995	25	1.000	4.97	0.993	25	1.000
waterno2_02	120.58%	4772	156.85%	1.000	3745	0.789	189.67%	1.000	3556	0.750
	≥ 10000%	9117	≥ 10000%	1.000	4815	0.533	≥ 10000%	1.000	5343	0.591
	≥ 10000%	7049	∞	1.000	8781	1.242	∞	1.000	5561	0.792
waterno2_03	≥ 10000%	7565	≥ 10000%	1.000	7365	0.974	≥ 10000%	1.000	7283	0.963
	≥ 10000%	10247	≥ 10000%	1.000	10978	1.071	≥ 10000%	1.000	9645	0.942
	≥ 10000%	14199	≥ 10000%	1.000	11408	0.805	≥ 10000%	1.000	9412	0.665
waterno2_04	≥ 10000%	7045	≥ 10000%	1.000	7204	1.022	≥ 10000%	1.000	7512	1.065
	≥ 10000%	13250	≥ 10000%	1.000	12072	0.912	≥ 10000%	1.000	11801	0.891
	≥ 10000%	9971	≥ 10000%	1.000	11974	1.199	≥ 10000%	1.000	11893	1.191
waterno2_06	≥ 10000%	2318	≥ 10000%	1.000	2943	1.258	≥ 10000%	1.000	2424	1.044
	≥ 10000%	4074	≥ 10000%	1.000	7181	1.744	≥ 10000%	1.000	4037	0.991
	≥ 10000%	4966	≥ 10000%	1.000	8806	1.758	≥ 10000%	1.000	4894	0.986
waterno2_09	≥ 10000%	871	≥ 10000%	1.000	1174	1.312	≥ 10000%	1.000	1174	1.312
	≥ 10000%	1447	≥ 10000%	1.000	1388	0.962	≥ 10000%	1.000	1388	0.962
	≥ 10000%	1921	≥ 10000%	1.000	1861	0.970	≥ 10000%	1.000	1726	0.904
waterno2_12	≥ 10000%	695	≥ 10000%	1.000	494	0.747	≥ 10000%	1.000	494	0.747
	≥ 10000%	627	≥ 10000%	1.000	1462	2.149	≥ 10000%	1.000	477	0.794
	≥ 10000%	568	≥ 10000%	1.000	1255	2.028	≥ 10000%	1.000	1255	2.028
waterno2_18	≥ 10000%	247	≥ 10000%	1.000	224	0.934	≥ 10000%	1.000	224	0.934
	≥ 10000%	429	≥ 10000%	1.000	599	1.321	≥ 10000%	1.000	599	1.321

continued on next page

Table E.3: Detailed computational results on nonconvex instances of MinlpLib.

	noconflict		nonlpinf				nlpinf			
Instance	T	N	T	T_Q	N	N_Q	T	T_Q	N	N_Q
	≥ 10000%	391	≥ 10000%	1.000	623	1.473	≥ 10000%	1.000	755	1.741
waterno2_24	≥ 10000%	638	≥ 10000%	1.000	468	0.770	≥ 10000%	1.000	468	0.770
	≥ 10000%	569	≥ 10000%	1.000	810	1.360	≥ 10000%	1.000	810	1.360
	≥ 10000%	1061	≥ 10000%	1.000	562	0.570	≥ 10000%	1.000	562	0.570
waters	1476.80%	40158	1476.80%	1.000	37388	0.931	1476.80%	1.000	39610	0.986
	1486.25%	37700	1486.25%	1.000	36819	0.977	1486.25%	1.000	40219	1.067
	1483.81%	39240	1490.84%	1.000	38994	0.994	1490.84%	1.000	32386	0.826
watersbp	1991.11%	38693	1950.70%	1.000	40806	1.054	1950.70%	1.000	40104	1.036
	1932.63%	40156	1928.13%	1.000	40607	1.011	1928.13%	1.000	38866	0.968
	1934.80%	39292	1972.45%	1.000	40119	1.021	1972.45%	1.000	38729	0.986
watersym1	70.43%	40213	70.43%	1.000	38450	0.956	82.62%	1.000	4501	0.114
	70.17%	40353	70.17%	1.000	38496	0.954	82.05%	1.000	4553	0.115
	70.94%	37608	70.93%	1.000	39397	1.047	84.73%	1.000	3109	0.085
watersym2	40.28%	37792	40.25%	1.000	36475	0.965	43.68%	1.000	13616	0.362
	40.69%	37724	40.69%	1.000	37244	0.987	50.09%	1.000	4732	0.128
	40.52%	38279	40.51%	1.000	39626	1.035	47.13%	1.000	4598	0.122
watertreatnd_conc	1231.35%	8427326	1231.35%	1.000	8436668	1.001	1231.35%	1.000	8441364	1.002
	1231.35%	8475781	1231.35%	1.000	8419421	0.993	1231.35%	1.000	8423226	0.994
watertreatnd_flow	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
	0.50	1	0.50	1.000	1	1.000	0.50	1.000	1	1.000
waterx	525.49%	13346	525.49%	1.000	8169	0.615	525.49%	1.000	8730	0.657
	525.49%	8429	525.49%	1.000	8345	0.990	525.49%	1.000	9250	1.096
	525.49%	8956	525.49%	1.000	9183	1.025	524.91%	1.000	8838	0.987
waterz	2129.22%	34978	2126.98%	1.000	33267	0.951	2120.96%	1.000	33600	0.961
	2103.47%	36263	2129.28%	1.000	34881	0.962	2129.28%	1.000	34629	0.955
	2100.71%	35012	2121.86%	1.000	34142	0.975	2121.86%	1.000	33948	0.970

Abstract

Mixed integer programming (MIP) is one of the essential paradigms used in business and industry decision making. In the last decades, it has been successfully applied to many real-world applications. One of the main benefits of using MIP is that it comes with a certificate of optimality. Proving that a given solution is optimal is equivalent to proving that there exists no better solution with respect to costs. In other words, if a solution is optimal, all other solutions are infeasible when considering an additional constraint enforcing better costs. Thus, proving infeasibility is an essential ingredient when solving MIPs. In this thesis, we shed light on infeasibility analysis in MIP. Modern MIP solvers try to "learn" from infeasibilities encountered during the solving process. However, compared to solving satisfiability problems (SAT), where the analysis of infeasibility has its origin, infeasibility analysis for MIP had an subordinate role so far. In this thesis, we show that a general purpose MIP solver such as SCIP can highly benefit when increasing the effort spend in detecting and exploiting infeasibility. This is shown in three different ways. Firstly, we develop a simultaneous approach of combinatorial and analytic infeasibility analysis. In addition, we develop several enhancements that further increase the positive impact on the overall solving process. Secondly, this thesis demonstrates that "learning" from almost infeasible subproblems of the search space is beneficial. Thirdly, we improve an existing method called Rapid Learning and develop new methods that explicitly aim to generate additional information of infeasibility. This newly generated information is used during the remainder of the solving process. In the last part of this thesis we generalize infeasibility analysis as known from solving MIP to general mixed integer nonlinear programs (MINLPs). This generalization is twofold. On the one hand, we present the concept of so-called local dual proofs to improve the performance of an LP-based branch-and-bound for solving nonconvex MINLPs. On the other hand, we develop a concept of nonlinear infeasibility analysis, extend SCIP to a fully-fledged NLP-based branch-and-bound, and construct nonlinear infeasibility proofs from convex NLP relaxations.

Zusammenfassung

Gemischt-ganzzahlige Optimierung (*mixed integer programming* (MIP)) ist eines der wesentlichen Paradigmen der Entscheidungsfindung in Unternehmen und Industrie. In den letzten Jahrzehnten wurde die gemischt-ganzzahlige Optimierung erfolgreich für viele reale Anwendungen genutzt. Ein großer Vorteile von MIP-Techniken besteht in der Verfügbarkeit eines Optimalitätszertifikats. Der Nachweis, dass eine bestimmte Lösung optimal ist, ist gleichbedeutend mit dem Nachweis, dass es keine bessere Lösung mit Hinblick auf die Kosten gibt. Mit anderen Worten, wenn eine Lösung optimal ist, sind alle anderen Lösungen unzulässig, sofern bessere Kosten über eine zusätzliche Nebenbedingung erzwungen werden. Der Nachweis der Unzulässigkeit ist daher ein wesentlicher Bestandteil bei der Lösung von MIPs. In dieser Arbeit beleuchten wir die Unzulässigkeitsanalyse beim Lösen von MIPs. Moderne MIP-Löser versuchen aus Unzulässigkeiten zu lernen, die während des Lösungsprozesses auftreten. Im Vergleich zur Lösung von Erfüllbarkeitsproblemen (*satisfiability problems* (SAT)), bei denen die Analyse der Unzulässigkeit ihren Ursprung hat, spielte die Analyse der Unzulässigkeit für MIPs bislang eine untergeordnete Rolle. In dieser Arbeit zeigen wir, dass ein allgemeiner MIP-Löser wie SCIP davon profitiert, wenn der Aufwand für das Erkennen und Ausnutzen von Unzulässigkeit erhöht wird. Dies wird auf drei verschiedene Arten gezeigt. Zunächst entwickeln wir einen simultanen Ansatz der kombinatorischen und analytischen Unzulässigkeitsanalyse. Darüber hinaus entwickeln wir verschiedene Verbesserungen, die die positiven Auswirkungen auf den gesamten Lösungsprozess weiter erhöhen. Zweitens zeigt diese Arbeit, dass das „Lernen“ auf der Basis von fast unzulässigen Teilproblemen des Suchraums von Vorteil ist. Drittens verbessern wir eine bestehende Methode namens Rapid Learning und entwickeln neue Methoden, die explizit darauf abzielen, zusätzliche Informationen über die Unzulässigkeit zu generieren. Diese neu generierten Informationen werden im weiteren Verlauf des Lösungsprozesses verwendet. Im letzten Teil dieser Arbeit verallgemeinern wir die Unzulässigkeitsanalyse, wie sie innerhalb des Lösungsprozess für MIPs genutzt wird, auf allgemeine gemischt-ganzzahlige nichtlineare Optimierungsprobleme (*mixed integer nonlinear programs* (MINLPs)). Diese Verallgemeinerung führen wir auf zwei unter-

schiedlichen Wegen durch. Einerseits präsentieren wir das Konzept sogenannter lokaler Dualbeweise zur Verbesserung der Lösegeschwindigkeit eines LP-basierten Branch-and-Bound-Verfahrens zur Lösung nicht konvexer MINLPs. Auf der anderen Seite entwickeln wir ein Konzept der nichtlinearen Unzulässigkeitsanalyse, erweitern SCIP mit einem vollwertiges NLP-basiertes Branch-and-Bound-Verfahren und konstruieren nichtlineare Unzulässigkeitsbeweise auf Basis konvexer NLP-Relaxierungen.