

# New Ideas for the Feasibility Pump: Using Multiple Reference Vectors

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Berlin, den 17 Juni 2021



Hiermit erkläre ich, dass ich die vorliegende Arbeit selbstständig und eigenhändig sowie ohne unerlaubte fremde Hilfe und ausschließlich unter Verwendung der aufgeführten Quellen und Hilfsmittel angefertigt habe.

Berlin, den 17 Juni 2021

A handwritten signature in black ink, appearing to read 'Gioni Mexi', enclosed within a hand-drawn rectangular box.

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Gioni Mexi



## Zusammenfassung

Gemischt-ganzzahlige Programmierung (MIP) wird häufig zur Modellierung und Lösung von Optimierungsproblemen verwendet, die sich aus realen Anwendungen ergeben. Diese Arbeit befasst sich mit der Feasibility Pump (FP) [29], die eine sehr bekannte Heuristik zum Finden von zulässigen Lösungen solcher MIP-Probleme ist. Aufgrund ihres Erfolges als eigenständiges Verfahren, ist FP auch in vielen modernen MIP-Lösern integriert. Zwei ihrer Hauptkomponenten sind der sogenannte *rounding step* und der *projection step*. Im *projection step* wird ein einzelner gerundeter Referenzvektor, d.h. ein Vector der die Integralitätsbeschränkungen des Problems erfüllt, auf die durch die linearen Nebenbedingungen definierte zulässige Region projiziert. Das Hauptziel von FP ist iterativ den Abstand der im *rounding step* und im *projection step* erhaltenen Vektoren zu reduzieren und dadurch gegen eine zulässige Lösung zu konvergieren. Falls die Hauptschleife keine zulässige Lösung findet, wird die sogenannte *enumeration stage* verwendet, die das ursprüngliche Problem löst nachdem die Zielfunktion durch die Manhattan-Distanz zu einem “fast” zulässigen gerundeten Vektor ersetzt wird.

Nach einer umfangreichen Literaturrecherche zu FP, schlagen wir in dieser Arbeit Modifikationen für den *projection step* und die *enumeration stage* vor, indem wir mehrere Referenzvektoren anstelle eines einzelnen Vektors nutzen. Zudem führen wir eine alternative Skalierung der Zielfunktion im *projection step* und ein neues Verfahren ein, um die Definitionsbereiche der Variablen in der *enumeration stage* zu verkleinern. Diese Ideen integrieren wir in eine Implementierung der FP und stellen eine weitere Schnittstelle zur Verfügung, sodass Anwender unsere und zahlreiche andere Versionen der FP auch mit dem nicht-kommerziellen Löser SCIP [31] nutzen können.

Experimente auf einem großen Testsatz von MIP-Instanzen zeigen, dass unsere Version der FP sowohl zu einer 9.8%igen Verbesserung der Lösungsqualität als auch zu einer Verringerungen der Laufzeit und der Iterationen um 4.0% bzw. 24.5% führt. Hierbei steigt insbesondere die Erfolgsrate in den ersten Iterationen erheblich an. So lassen sich beispielsweise 52.2% mehr Instanzen innerhalb der ersten zehn Iterationen lösen. Zudem ist unsere verbesserte Version der FP sehr effizient darin, innerhalb weniger Minuten Lösungen für schwierige MIP-Instanzen zu finden. Dies zeigen beispielsweise die Ergebnisse auf den Instanzen der *International Timetabling Competition 2021* [50]. In einigen Fällen ist sie sogar in der Lage, zulässige Lösungen für Instanzen zu finden, bei denen eine enorme Anzahl von parallel laufenden kommerziellen MIP-Lösern auf 12288 CPU-Kernen eines Supercomputers keinen Erfolg hatten.



## Abstract

Mixed integer programming (MIP) is widely used for modelling and solving optimization problems that arise from real-world applications. This thesis is all about the Feasibility Pump (FP) [29], which is a well-known primal heuristic for finding feasible solutions for MIP instances. Because of its success as a standalone procedure, FP is also integrated in many state-of-the-art MIP solvers. Two of its main components are the so-called *rounding step* and *projection step*. In the projection step, a single rounded reference vector, i.e., a vector that satisfies the integrality constraints of the problem, is projected back to the feasible region defined by the linear constraints. The main goal of FP is to iteratively close the distance of vectors obtained in the rounding step and the projection step, and thereby converge to a feasible solution. As a last resort, FP applies a so-called *enumeration stage*, where the original problem is solved after replacing the objective function by the Manhattan distance to an “almost” feasible rounded vector.

In this thesis, besides an extensive literature review regarding FP, we propose modifications of the projection step and the enumeration stage, by considering multiple reference vectors instead of a single one. Moreover, we introduce alternative scalings for the objective function in the projection step and a new tightening procedure for the variable domains in the enumeration stage. We incorporate our ideas in an implementation of FP and provide an additional solver interface that enables practitioners to use our, and numerous other versions of FP also with the non-commercial solver SCIP [31].

Computational experiments over a large test set of MIP instances show that our modifications boost the performance of FP. Namely, they provide a 9.8% solution quality improvement and simultaneously 4.0% decreased running time and 24.5% less iterations. Especially the success rate within the first few iterations increases considerably. For instance, we are able to find solutions for 52.2% more instances within ten iterations. Lastly, our improved version of FP is very efficient in finding feasible solutions within minutes for difficult instances from the *International Timetabling Competition 2021* [50]. In some cases, we are even able to find solutions for instances where a massive number of parallel runs of commercial MIP solvers on 12288 CPU cores of a supercomputer could not.





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Mixed integer programming (MIP) is widely used for modelling and solving hard optimization problems that arise from real-world applications in areas such as vehicle routing, telecommunications, job-scheduling [17, 28, 40], and many more. Even though solving such problems is an NP-hard task, the capabilities of MIP solvers have remarkably improved over the years. One major factor of this performance improvement are primal heuristic, which are algorithms embedded in MIP solvers that aim at finding good quality feasible solutions in a short amount of time.

The Feasibility Pump (FP) is one of the most cited primal heuristics and because of its success as a standalone procedure, it is also embedded in many state-of-the-art commercial MIP solvers, e.g., the FICO Xpress Optimizer [25], IBM ILOG CPLEX [37], and also non-commercial MIP solvers, e.g., SCIP [31]. It was originally developed by Fischetti et al. [29] for binary MIP problems and then generalized for problems with general integer variables by Bertacco et al. [4]. Over the last 15 years FP gained the attention of many researchers that further developed the algorithm and proved interesting theoretical properties.

Our goal is to improve the performance of FP by modifying some of its main components, and to provide a flexible open-source implementation which can be used by practitioners dealing with hard MIP problems, and by researchers as a baseline for future works regarding FP. In the remainder of this chapter we present general concepts and notation for MIP, briefly review categories of primal heuristics, and describe FP in detail.

## **1.1. Mixed Integer Programming**

In this section we provide important definitions and the notation that we use throughout this thesis. For a comprehensive introduction to linear and integer programming we refer to [51, 52].

**Definition 1.1.** (*mixed integer program*) Let  $m, n \in \mathbb{Z}_{\geq 0}$ . Given some matrix  $A \in \mathbb{R}^{m \times n}$ , vectors  $b \in \mathbb{R}^m$ ,  $c \in \mathbb{R}^n$ ,  $l, u \in \mathbb{R}^n \cup \{\pm\infty\}$ , and a set of indices  $\mathcal{I} \subseteq \mathcal{N} := \{1, \dots, n\}$ , a problem in the form

$$\begin{aligned} \min_{x \in \mathbb{R}^n} \quad & c^\top x \\ \text{s.t.} \quad & Ax \leq b \\ & l \leq x \leq u \\ & x_j \in \mathbb{Z} \quad \text{for all } j \in \mathcal{I}, \end{aligned} \tag{1.1}$$

is called a *mixed integer program (MIP)*.

The term  $c^\top x$  is called the *objective function*, or shortly *objective*. The vectors  $l$  and  $u$  bound the vector of *variables*  $x$  and are called *lower* and *upper bound* vector, respectively. Moreover, we call  $Ax \leq b$  *linear constraints*,  $l \leq x \leq u$  *bounding constraints*, and  $x_j \in \mathbb{Z}$  for all  $j \in \mathcal{I}$  *integrality constraints*. The *domain*  $D \in \mathbb{R}^n$  of the variables  $x$  is defined as the set of vectors that satisfy the bounding and integrality constraints. The vectors of the set

$$P_{\text{MIP}} := \{x \in \mathbb{R}^n \mid Ax \leq b, l \leq x \leq u, x_j \in \mathbb{Z} \text{ for all } j \in \mathcal{I}\}$$

are called *feasible solutions* of the MIP. A feasible solution  $x^* \in P_{\text{MIP}}$  is called *optimal*, if for all  $x \in P_{\text{MIP}}$  it holds that  $c^\top x^* \leq c^\top x$ . If the set  $P_{\text{MIP}}$  is empty the MIP is *infeasible*.

By an abuse of terminology, we call any vector  $x \in \mathbb{R}^n$  that satisfies all integrality constraints an *integer vector* for the MIP and any vector that satisfies only the linear and bounding constraints a *fractional vector*. Furthermore, we use the abbreviation MIP for a mixed integer program and the concept of mixed integer programming simultaneously. The referred term will be easily implied by the context of the sentence.

Depending on the set  $\mathcal{I}$  and the bounds  $l, u$ , we define the following subsets of the variable indices  $\mathcal{N}$ :

- binary indices:  $\mathcal{B} := \{j \in \mathcal{I} \mid l_j = 0 \text{ and } u_j = 1\}$ ,
- general integer indices:  $\mathcal{G} := \mathcal{I} \setminus \mathcal{B}$ ,
- continuous indices:  $\mathcal{K} := \mathcal{N} \setminus \mathcal{I}$ .

For any integer variable  $x_j \in \mathcal{I}$ , we can assume that  $l_j, u_j \in \mathbb{Z} \cup \{\pm\infty\}$ . In particular, if  $l_j$  is finite but not integer, we can set its value to  $\lceil l_j \rceil$  without removing any feasible solution from  $P_{\text{MIP}}$ . Similarly,  $u_j$  can be set to  $\lfloor u_j \rfloor$ . Moreover, we define the following special types of MIPs:

- *linear program (LP)*: if  $\mathcal{I} = \emptyset$ ,

- 0-1 MIP:                                   if  $\mathcal{B} = \mathcal{I} \subset \mathcal{N}$ ,
- integer program (IP):               if  $\mathcal{G} = \mathcal{N}$ ,
- binary program (BP):               if  $\mathcal{B} = \mathcal{N}$ .

To measure the quality of a feasible solution of a MIP w.r.t. an optimal (or best known) solution, we use the notion of the primal gap.

**Definition 1.2.** (*primal gap*) Let  $\tilde{x}$  be a feasible solution of a MIP in the form (1.1), and  $x^*$  be an optimal (or best known) solution of that MIP. The primal gap  $\gamma \in \mathbb{R}_{\geq 0}$  of  $\tilde{x}$  is defined as:

$$\gamma(\tilde{x}) := \begin{cases} 0, & \text{if } c^\top x^* = c^\top \tilde{x} = 0, \\ \frac{|c^\top x^* - c^\top \tilde{x}|}{|c^\top x^*|}, & \text{if } c^\top x^* \cdot c^\top \tilde{x} > 0, \\ \infty & \text{otherwise.} \end{cases}$$

If we omit the integrality constraints from a MIP, we obtain its LP relaxation.

**Definition 1.3.** (*LP relaxation of a MIP*) Given a MIP in the form (1.1). The problem

$$\begin{aligned} \min_{x \in \mathbb{R}^n} \quad & c^\top x \\ \text{s.t.} \quad & Ax \leq b \\ & l \leq x \leq u \end{aligned}$$

is called the LP relaxation of the MIP.

The vectors of the set

$$P_{\text{LP}} := \{x \in \mathbb{R}^n \mid Ax \leq b, l \leq x \leq u\}$$

are called *feasible solutions* of the LP relaxation. A feasible solution  $x^* \in P_{\text{LP}}$  is called *LP-optimal*, if for all  $x \in P_{\text{LP}}$  it holds that  $c^\top x^* \leq c^\top x$ . Note, that  $P_{\text{LP}}$  is a superset of  $P_{\text{MIP}}$ , i.e.,  $P_{\text{MIP}} \subseteq P_{\text{LP}}$ . Therefore, for any MIP in the form (1.1), the objective value of an LP-optimal solution provides a lower bound on the objective value of any feasible solutions  $x \in P_{\text{MIP}}$ .

Throughout this thesis we round vectors of  $\mathbb{R}^n$  and measure their distance, w.r.t. a set  $\mathcal{J} \subseteq \{1, \dots, n\}$ . For this purpose we use the following rounding and distance functions.

**Definition 1.4.** (*rounding w.r.t.  $\mathcal{J}$* ) A rounding of a vector  $\bar{x} \in \mathbb{R}^n$  w.r.t. a set of indices  $\mathcal{J} \subseteq \{1, \dots, n\}$  is denoted as  $\tilde{x} := [\bar{x}]^{\mathcal{J}}$  and is obtained by setting  $\tilde{x}_j = [\bar{x}_j]$  for any  $j \in \mathcal{J}$  and  $\tilde{x}_j = \bar{x}_j$  otherwise, where  $[\cdot]$  represents a scalar rounding to an integer.

**Definition 1.5.** ( $\tau$ -rounding w.r.t.  $\mathcal{J}$ ) Let  $\tau \in [0, 1)$ . The  $\tau$ -rounding of a vector  $\bar{x} \in \mathbb{R}^n$  w.r.t. a set of indices  $\mathcal{J} \subseteq \{1, \dots, n\}$  is denoted as  $\tilde{x} := \lfloor \bar{x} + \tau \rfloor^{\mathcal{J}} \in \mathbb{R}^n$ , and is obtained by setting  $\tilde{x}_j := \lfloor \bar{x}_j + \tau \rfloor$  if  $j \in \mathcal{J}$  and  $\tilde{x}_j := \bar{x}_j$  otherwise. For the special case of  $\tau = 0.5$  we obtain the so-called nearest rounding w.r.t.  $\mathcal{J}$ .

**Definition 1.6.** ( $L_1$ -distance w.r.t.  $\mathcal{J}$ ) The  $L_1$ -distance between any two vectors  $\bar{x}, \tilde{x} \in \mathbb{R}^n$  w.r.t. a set  $\mathcal{J} \subseteq \{1, \dots, n\}$  is defined as

$$\Delta^{\mathcal{J}}(\bar{x}, \tilde{x}) := \|\bar{x} - \tilde{x}\|_1^{\mathcal{J}} = \sum_{i \in \mathcal{J}} |\bar{x}_i - \tilde{x}_i| \quad (1.2)$$

**Remark 1.7.** Consider a MIP in the form (1.1), a vector  $\bar{x} \in P_{LP}$ , and an integer vector  $\tilde{x}$  w.r.t. the set of indices  $\mathcal{I}$ . If the  $L_1$ -distance  $\Delta^{\mathcal{I}}(\bar{x}, \tilde{x})$  is equal to 0, the integer components of  $\bar{x}$  coincide with those in  $\tilde{x}$ . Thus  $\bar{x}$  satisfies the integrality constraints too, and we have  $\bar{x} \in P_{MIP}$ .

Similar to Definition 1.6, we define the  $L_2$ -distance w.r.t. a set  $\mathcal{J} \subseteq \{1, \dots, n\}$  as follows.

**Definition 1.8.** ( $L_2$ -distance w.r.t.  $\mathcal{J}$ ) The  $L_2$ -distance between any two vectors  $\bar{x}, \tilde{x} \in \mathbb{R}^n$  w.r.t. a set  $\mathcal{J} \subseteq \{1, \dots, n\}$  is defined as

$$\Delta_2^{\mathcal{J}}(\bar{x}, \tilde{x}) := \|\bar{x} - \tilde{x}\|_2^{\mathcal{J}} = \sqrt{\sum_{i \in \mathcal{J}} (\bar{x}_i - \tilde{x}_i)^2}. \quad (1.3)$$

## 1.2. Primal Heuristics

The core of any MIP solver is the so-called LP-based branch-and-bound algorithm (B&B), which recursively partitions the set of feasible solutions  $P_{MIP}$  into a search tree, and along the way uses the bounds obtained by LP relaxations to prune parts of the tree that cannot contain an optimal solution. This process is guaranteed to find an optimal solution in a finite amount of time. However, the worst case running time is exponential in the size of the problem instance.

Even though solving a MIP is in general an NP-hard problem, the capabilities of MIP solvers have remarkably improved over the years. One of the biggest contributors to this improvement is the use of primal heuristics. Primal heuristics are applied during the solving process and their goal is to find good quality feasible solutions in short amounts of time. In contrast to B&B, they are incomplete methods, which means that they provide no guarantee on finding a feasible solution. Nevertheless, having a feasible solution at hand at an early stage of the solving process can be beneficial in many ways. First, it proves that the MIP is feasible. Second, practitioners may be satisfied with a sufficiently good quality solution found by a heuristic and can therefore stop the solving process at an earlier stage. Moreover, feasible solutions can prove useful in tightening the



problem formulation and pruning parts of the search tree generated by the B&B algorithm.

Based on their rationale, primal heuristics can be grouped in various categories, for example:

- *Rounding heuristics* take as input a vector  $\bar{x} \in P_{\text{LP}}$ , and apply rounding techniques to the set of integer variables.
- *Diving heuristics* start with a vector  $\bar{x} \in P_{\text{LP}}$ , and in each iteration some integer variables are fixed to integer values and the LP relaxation of the resulting problem is solved.
- *Objective diving heuristics* start with a vector  $\bar{x} \in P_{\text{LP}}$ , and in each iteration the LP relaxation is resolved after modifying the objective function in a way that may lead to solutions violating less integrality constraints.
- *Improvement heuristics* differ from the previous types of heuristics, since they require as input at least one feasible solution. Such heuristics try to find feasible solutions with better objective value, for example by searching in the neighborhood of previously found feasible solutions.

Note that heuristics may be used in various stages of the solving process and that they can also be combined. For example, an improvement heuristic may be applied to improve a solution found by a rounding, diving, or objective diving heuristic. We refer readers interested in the topic of primal heuristics to Berthold [5, 7].

### 1.3. Basic Feasibility Pump

The Feasibility Pump (FP) is an objective diving heuristic introduced by Fischetti et al. [29]. In Algorithm 1.1 we outline the core idea of FP. The details of the algorithm will be explained in the next section. The algorithm takes as input a MIP  $P$  in the form (1.1) and is initialized with the optimal solution of its LP relaxation  $\bar{x}^0$ . The iterative process (lines 1-9) is called the *pumping loop*. A single iteration of the pumping loop is called a *pumping iteration*. In the pumping loop, the algorithm constructs two sequences of vectors  $\{\bar{x}^k\}_{k=1}^K$  and  $\{\tilde{x}^k\}_{k=1}^K$  for a finite  $K$ , that satisfy the feasibility requirements in a complementary way. More specific, the first sequence contains vectors of  $P_{\text{LP}}$  and the second contains integer vectors, i.e., vectors that satisfy the integrality constraints of  $P$ , but do not necessarily lie in  $P_{\text{LP}}$ . In every pumping iteration  $k$ , the vector  $\tilde{x}^k$  is obtained in the rounding step (line 5), by rounding all values  $\bar{x}_j^{k-1} \notin \mathbb{Z}$  with  $j \in \mathcal{I}$  to an integer. The vector  $\bar{x}^k$  is obtained in the projection step (line 9) by solving the

optimization problem

$$\begin{aligned} \min_{x \in \mathbb{R}^n} \quad & \Delta^{\mathcal{I}}(x, \tilde{x}^k) \\ \text{s.t.} \quad & x \in P_{\text{LP}}. \end{aligned} \tag{1.4}$$

The mathematical problem (1.4) is a nonlinear problem (NLP), since it contains absolute values in its objective function. However, it can be reformulated as an LP, as we are going to explain in the next section. The algorithm terminates with a feasible solution of the MIP (line 4), if the solution of the projection step satisfies the integrality constraints. Otherwise, the algorithm terminates unsuccessfully after a termination criterion is met.

One major issue of FP is cycling. In any pumping iteration  $k'$  it can happen that  $\tilde{x}^{k'} = \tilde{x}^r$  for some  $r \in \{1, \dots, k' - 1\}$ . This would yield  $\bar{x}^{k'} = \bar{x}^r$  in the projection step, and by assuming a deterministic rounding procedure, e.g., nearest rounding, the same subsequences of vectors  $\tilde{x}^{r+1}, \dots, \tilde{x}^{k'}$  and  $\bar{x}^{r+1}, \dots, \bar{x}^{k'}$  are repeated. Thus, the algorithm stalls. This issue can be resolved by applying a slight perturbation on  $\tilde{x}^{k'}$  (line 8), e.g., by flipping the value of  $\tilde{x}_j^{k'}$  to the opposite rounding of  $\bar{x}_j^{k'-1}$  for all indices  $j \in J$  in a subset  $J \subseteq \mathcal{I}$ .

---

**Algorithm 1.1:** Feasibility Pump (core idea)

---

**Input** : A MIP  $P$  in the form (1.1)  
**Initialization:**  $\bar{x}^0 \leftarrow \arg \min\{c^\top x : x \in P_{\text{LP}}\}$ ,  $k \leftarrow 0$   
**Output** : A feasible solution of  $P$  or  $\emptyset$  if none found

```

1 while (not termination condition) do
2    $k \leftarrow k + 1$ 
3   if  $\bar{x}^{k-1} \in P_{\text{MIP}}$  then
4     return  $\bar{x}^{k-1}$ 
5    $\tilde{x}^k \leftarrow \text{round}(\bar{x}^{k-1}, \mathcal{I})$  /* Rounding step */
6   if  $\tilde{x}^k = \tilde{x}^r$  for some  $r \in \{1, \dots, k - 1\}$  then
7     choose  $J \subseteq \mathcal{I}$ 
8      $\tilde{x}^k \leftarrow \text{perturb}(\tilde{x}^k, J)$  /* Perturbation step */
9    $\bar{x}^k \leftarrow \arg \min\{\Delta^{\mathcal{I}}(x, \tilde{x}^k) : x \in P_{\text{LP}}\}$  /* Projection step */
10 return  $\emptyset$ 

```

---

**Example 1.9.** Consider the BP

$$\begin{aligned} \min \quad & -2x_1 - x_2 \\ \text{s.t.} \quad & 4x_1 + 2x_2 \leq 3 \\ & -25x_1 + 40x_2 \leq 18 \\ & 5x_1 - x_2 \leq 2 \\ & x_1, x_2 \in \{0, 1\}. \end{aligned}$$

The set of feasible solutions  $P_{LP}$  of the LP relaxation of this BP is the blue polytope depicted in Figure 1.1. In this example we assume that the rounding step of FP always rounds to the nearest integer. The algorithm is initialized with the optimal solution  $\bar{x}^0 = (0.5, 0.5)$  of the LP relaxation. In the first pumping iteration,  $\bar{x}^0$  is rounded to  $\tilde{x}^1 = (1, 1)$ . The solution of the projection step is the closest point to  $P_{LP}$ , w.r.t. the  $L_1$ -distance to  $\tilde{x}^1$ , and is the LP-feasible vector  $\bar{x}^1 = (0.4, 0.7)$ . Since  $\bar{x}^1$  is not a feasible solution, it is rounded in the next iteration to  $\tilde{x}^2 = (0, 1)$ . The projection step returns the vector  $\bar{x}^2 = (0, 0.45)$ , which is still not feasible, and therefore it is rounded in the next iteration to  $\tilde{x}^3 = (0, 0)$ . The solution of the projection step is  $\bar{x}^3 = \tilde{x}^3$ , which is a feasible solution for the BP. Thus, FP terminates successfully.

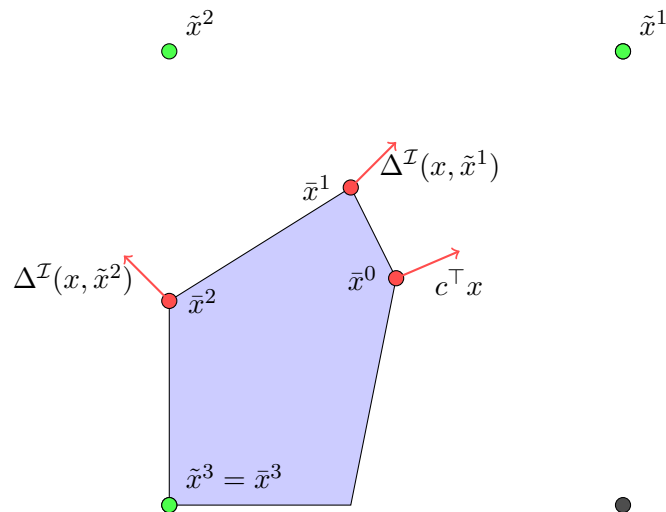


Figure 1.1.: Applying FP to a BP with two variables.

## 1.4. The Feasibility Pump in Detail

The computational experiments in [29] show that FP has a satisfactory success rate for finding feasible solutions for 0-1 MIPs. However, for MIPs with both binary and integer variables, the success rate of FP is lower, and the algorithm is more likely to cycle. A possible reason for the increased cycling frequency is that in each pumping iteration the rounding and perturbation procedure do not consider all possible values from the domains of general integer variables, but only the two closest integer values to the solution of the projection step.

Many optimization algorithms incorporate various ideas and techniques based on the problem type. For example, when dealing with general MIPs, solvers may first branch on binary variables before considering general integers. Branching on a binary variable, fixes its value to 0 in one subproblem and to 1 in the second, which in many cases enforces a more powerful constraint than splitting the domain

of an integer variable in two parts. Inspired by this idea, Bertacco et al. [4] choose to split FP in multiple stages as explained in the next part of this section. After that, we dive into the details of the rounding, projection, and perturbation steps, and describe the termination criteria that are used. At last, we discuss strategies to improve the solution quality of feasible solutions found by FP.

### FP in Stages

Bertacco et al. [4] choose to split FP in stages as shown in Algorithm 1.2. The algorithm is initialized with a MIP  $P$  in the form (1.1). A description of the pumping loop is given in Algorithm 1.4 and will be discussed in detail later. In the first stage of Algorithm 1.2, *Stage 1*, the integrality constraints of general integer variables are relaxed. Hence, the goal of Stage 1 is to find a feasible solution of the following 0-1 MIP

$$\begin{aligned} \min_{x \in \mathbb{R}^n} \quad & c^\top x \\ \text{s.t.} \quad & Ax \leq b \\ & l \leq x \leq u \\ & x_j \in \mathbb{Z} \quad \forall j \in \mathcal{B}. \end{aligned} \tag{1.5}$$

The pumping loop is initialized with the MIP  $P$ , the set of indices of binary variables  $\mathcal{B}$ , and the solution  $\bar{x}^0$  of its LP relaxation. In the rounding step of any pumping iteration  $k$ , the vector  $\tilde{x}^k$  is obtained by rounding  $\bar{x}^{k-1}$  w.r.t. the index set of binaries  $\mathcal{B}$ , and the projection step solves the problem

$$\begin{aligned} \min_{x \in \mathbb{R}^n} \quad & \Delta^{\mathcal{B}}(x, \tilde{x}^k) \\ \text{s.t.} \quad & x \in P_{\text{LP}}. \end{aligned} \tag{1.6}$$

In the fortunate case that the pumping loop terminates with a solution satisfying the integrality constraints of all variables in  $\mathcal{I}$ , a feasible solution of  $P$  is found and the algorithm terminates. Otherwise, the next stage, *Stage 2*, starts and is initialized with information obtained from Stage 1. More precisely, if Stage 1 terminates with a feasible solution  $\tilde{x}^*$  of (1.5), then the integrality constraints of general integer variables are restored and the pumping loop starts again, initialized with the MIP  $P$ , the set of indices of both binary and integer variables  $\mathcal{B} \cup \mathcal{G}$ , and  $\tilde{x}^*$  instead of the solution of the LP relaxation of  $P$ . If Stage 1 terminates after say  $K_1$  iterations without a solution of (1.5), then again, the integrality constraints of general integer variables are restored, but this time the initialization vector of Stage 2 is a rounded vector  $\tilde{x}^*$  from Stage 1 with smallest  $L_1$ -distance, w.r.t.  $\mathcal{B}$ , from  $P_{\text{LP}}$ , i.e.,

$$\tilde{x}^* \in \arg \min_{\tilde{x}^i \in \{\tilde{x}^1, \dots, \tilde{x}^{K_1}\}} \Delta^{\mathcal{B}}(\tilde{x}^i, \tilde{x}^i). \tag{1.7}$$

**Algorithm 1.2:** Feasibility Pump In Stages

---

**Input** : A MIP  $P$  in the form (1.1)  
**Parameters** :  $\maxIterS1, \maxIterNoImprS1, \maxRestS1, \maxIterS2, \maxIterNoImprS2, \maxRestS2, \text{avgPert} \in \mathbb{N}$   
**Output** : A MIP feasible solution  $\tilde{x}^*$  or  $\emptyset$  if none found

```

1  $\bar{x}^0 \leftarrow \arg \min \{c^\top x : x \in P_{LP}\}$ 
2 if  $\mathcal{B} \neq \emptyset$  then
3    $\tilde{x}^* \leftarrow \text{pumpingLoop}(P, \mathcal{B}, \bar{x}^0; S1 \text{ parameters})$  /* Stage 1 */
4   if  $\tilde{x}^*$  MIP feasible then
5     return  $\tilde{x}^*$ 
6    $\tilde{x}^* \leftarrow \text{pumpingLoop}(P, \mathcal{B} \cup \mathcal{G}, \bar{x}^0; S2 \text{ parameters})$  /* Stage 2 */
7 else /* Skip directly to Stage 2 */
8    $\tilde{x}^* \leftarrow \text{pumpingLoop}(P, \mathcal{G}, \bar{x}^0; S2 \text{ parameters})$ 
9 if  $\tilde{x}^*$  MIP feasible then
10  return  $\tilde{x}^*$ 
11 return  $\arg \min \{\Delta^{\mathcal{I}}(x, \tilde{x}^*) \mid x \in P_{MIP}\}$  /* Stage 3 */
```

---

Note that Stage 2 takes place also in case of 0-1 MIPs. Lastly, for IPs, i.e., for  $\mathcal{B} = \emptyset$ , Stage 1 is skipped and Stage 2 is initialized with the LP-optimum  $\bar{x}^0$ .

As a last resort, if both Stage 1 and 2 are unsuccessful, a so-called *enumeration stage*, also known as *Stage 3*, is employed. The main idea of Stage 3 is to search for feasible solutions in the vicinity of an “almost” feasible integer vector. More specific, Stage 3 solves the original MIP  $P$  after replacing the objective function by the  $L_1$ -distance  $\Delta^{\mathcal{I}}(x, \tilde{x}^*)$ , where  $\tilde{x}^*$  is the closest integer vector to the polyhedron  $P_{LP}$  obtained from the previous stage. If the previous stage is Stage 1, and terminated after  $K_1$  iterations without a feasible solution for  $P$ , then  $\tilde{x}^*$  is given by (1.7). In case the previous stage is Stage 2, and terminated after  $K_2$  iterations without a feasible solution for  $P$ , then  $\tilde{x}^*$  is given by,

$$\tilde{x}^* \in \arg \min_{\tilde{x}^i \in \{\tilde{x}^1, \dots, \tilde{x}^{K_2}\}} \Delta^{\mathcal{I}}(\tilde{x}^i, \tilde{x}^i). \quad (1.8)$$

Note that in (1.8) the integer vectors  $\tilde{x}^1, \dots, \tilde{x}^{K_2}$  are the ones obtained in Stage 2. In the following, we denote by  $\mathcal{J}$  the index set of integer variables in the current stage of FP, i.e.,  $\mathcal{J} = \mathcal{B}$  in Stage 1, and  $\mathcal{J} = \mathcal{I} = \mathcal{B} \cup \mathcal{G}$  in Stage 2 and 3.

### Rounding Step

The most intuitive and first rounding function incorporated in FP is nearest rounding w.r.t. the index set of integer variables  $\mathcal{J}$  of the current stage. Note that in any pumping iteration  $k$ , if the rounded vector  $\tilde{x}^k$  coincides with an

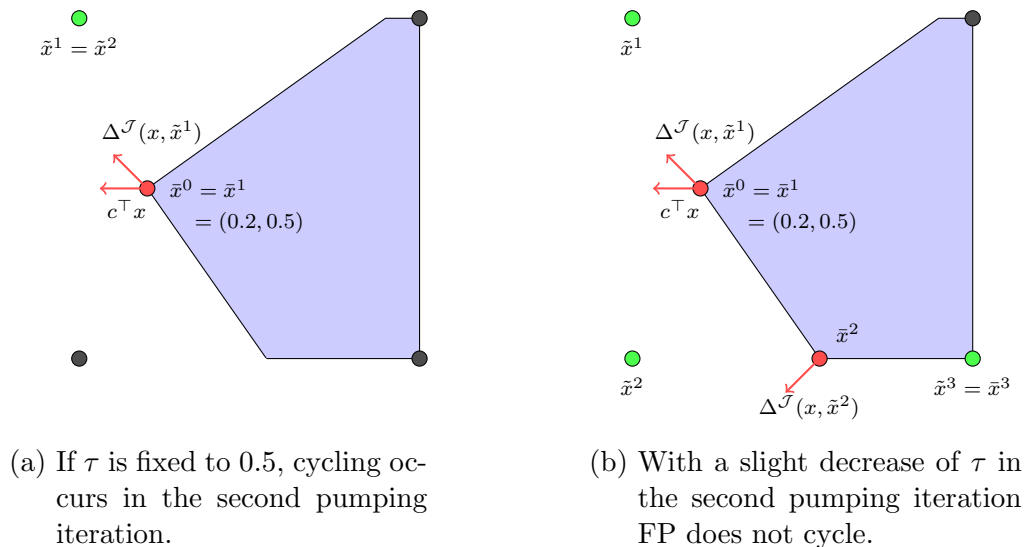


Figure 1.2.: Perturbing the rounding function may decrease the cycling frequency.

integer vector obtained in a previous iteration, a random perturbation procedure is applied on some components of  $\tilde{x}^k$  in order to prevent cycling. However, frequent calls of the perturbation procedure can lead to a poor performance. To reduce the frequency of cycling, the authors in [4] suggest to slightly perturb the rounding function in each pumping iteration. In particular, instead of using the rounding function  $[\cdot] := \lfloor \cdot + \tau \rfloor$  for all  $j \in \mathcal{J}$  with a fixed parameter  $\tau \in [0, 1)$ , e.g.,  $\tau = 0.5$  for the nearest rounding, they update  $\tau$  in each pumping iteration. The parameter  $\tau$  is computed as

$$\tau(\omega) := \begin{cases} 2\omega(1 - \omega), & \text{if } \omega \leq \frac{1}{2} \\ 1 - 2\omega(1 - \omega), & \text{if } \omega > \frac{1}{2} \end{cases}$$

where  $\omega$  is a uniformly random variable in  $[0, 1)$ . As an example consider the BP with two binary variable from Figure 1.2. In Figure 1.2a FP runs with  $\tau$  fixed to 0.5. In the first iteration, the solution of the LP relaxation  $\bar{x}^0 = (0.2, 0.5)$  is rounded to  $\tilde{x}^1 = (0, 1)$  and the projection step returns the vector  $\bar{x}^1 = \bar{x}^0$ . Since  $\tau$  is fixed,  $\tilde{x}^2$  coincides with  $\tilde{x}^1$ . Thus, FP cycles and the perturbation procedure has to be used. In Figure 1.2b  $\tau$  is updated in each iteration. For instance, if in the second iteration  $\tau$  becomes less than 0.5, then  $\bar{x}^1$  is rounded to  $\tilde{x}^2 = (0, 0)$ . Hence, cycling is avoided here.

### Projection Step

As already mentioned, the vectors of the sequence  $\{\bar{x}^k\}_{k=1}^K$  are LP-feasible, but do not satisfy the integrality constraints, whereas those in  $\{\tilde{x}^k\}_{k=1}^K$  satisfy the integrality constraints, but are not LP-feasible. The goal of the projection step is to gradually reduce the  $L_1$ -distance between  $\bar{x}^k$  and  $\tilde{x}^k$  w.r.t.  $\mathcal{J} = \mathcal{B}$  in Stage

1, or  $\mathcal{J} = \mathcal{I}$  in Stage 2. We say that the sequences converge in an iteration  $k$  if  $\Delta^{\mathcal{J}}(\bar{x}^k, \tilde{x}^k)$  is equal to 0. At convergence, an integer vector w.r.t.  $\mathcal{J}$  is found and the current stage terminates. The nonlinear problem of the projection step

$$\begin{aligned} \min_{x \in \mathbb{R}^n} \quad & \Delta^{\mathcal{J}}(x, \tilde{x}^k) \\ \text{s.t} \quad & x \in P_{\text{LP}}. \end{aligned} \tag{1.9}$$

is equivalent to the LP

$$\begin{aligned} \min \quad & \sum_{j \in \mathcal{J} : \tilde{x}_j^k = l_j} (x_j - l_j) + \sum_{j \in \mathcal{J} : \tilde{x}_j^k = u_j} (u_j - x_j) + \sum_{j \in \mathcal{J} : l_j < \tilde{x}_j^k < u_j} d_j \\ \text{s.t} \quad & x \in P_{\text{LP}} \\ & d_j \geq \tilde{x}_j^k - x_j, \quad \text{for all } j \in \mathcal{J} : l_j < \tilde{x}_j^k < u_j \\ & d_j \geq x_j - \tilde{x}_j^k, \quad \text{for all } j \in \mathcal{J} : l_j < \tilde{x}_j^k < u_j \\ & d_j \in \mathbb{R}, \quad \text{for all } j \in \mathcal{J} : l_j < \tilde{x}_j^k < u_j. \end{aligned} \tag{1.10}$$

The equivalence of (1.9) and (1.10) is easy to show. For all  $j \in \mathcal{J}$  with  $\tilde{x}_j^k = l_j$ , it holds that  $|x_j - \tilde{x}_j^k| = x_j - l_j$ , since for any  $x \in P_{\text{LP}}$ ,  $x_j$  is bounded from below by  $l_j$ . For  $j \in \mathcal{J}$  with  $\tilde{x}_j^k = u_j$ , it holds that  $|x_j - \tilde{x}_j^k| = u_j - x_j$ , since for any  $x \in P_{\text{LP}}$ ,  $x_j$  is bounded from above by  $u_j$ . Finally, for  $j \in \mathcal{J}$  with  $l_j < \tilde{x}_j^k < u_j$  an auxiliary variable  $d_j \in \mathbb{R}$  is introduced and replaces  $|x_j - \tilde{x}_j^k|$  in the objective function. To ensure that  $d_j$  is equal to  $|x_j - \tilde{x}_j^k|$ , we add the linear constraints

$$\begin{aligned} d_j &\geq \tilde{x}_j^k - x_j \\ d_j &\geq x_j - \tilde{x}_j^k. \end{aligned}$$

Note that the additional variables and constraints are only considered in the projection step.

### Perturbation Procedure

During the pumping loop it can happen that the current integer vector  $\tilde{x}^k$  is the same as  $\tilde{x}^{k-1}$ . In this case, a perturbation procedure is applied to  $\tilde{x}^k$ , which means that a small number of its integer components are chosen and their value is flipped. Flipping a value of an integer component  $\tilde{x}_j^k$  with  $j \in \mathcal{J}$  simply means that if  $\tilde{x}_j^k = \lfloor \bar{x}_j^{k-1} \rfloor$ , then  $\tilde{x}_j^k$  is set to  $\lceil \bar{x}_j^{k-1} \rceil$ , otherwise  $\tilde{x}_j^k$  is set to  $\lfloor \bar{x}_j^{k-1} \rfloor$ . To be more precise, a random integer number  $p$  from  $[\frac{\text{avgPert}}{2}, \frac{3 \cdot \text{avgPert}}{2}]$  is generated, where  $\text{avgPert} \in \mathbb{N}$  is fixed and denotes the average number of components of  $\tilde{x}^k$  whose values are going to be changed. In the original FP publication  $\text{avgPert}$  is equal to 20. Remember, that the goal of FP is to reduce the  $L_1$ -distance w.r.t. to  $\mathcal{J}$  between vectors of the two sequences  $\{\bar{x}^k\}_k$ , and  $\{\tilde{x}^k\}_k$ . Obviously, randomly

picking  $p$  integer components of  $\tilde{x}^k$  and flipping their values may result in a large increase of the distance  $\Delta^{\mathcal{J}}(\bar{x}^{k-1}, \tilde{x}^k)$  and could possibly prevent convergence to a feasible solution. Therefore, the perturbation procedure aims at flipping the value of components of  $\tilde{x}^k$ , such that the distance  $\Delta^{\mathcal{J}}(\bar{x}^{k-1}, \tilde{x}^k)$  remains as small as possible. To that end, we compute for every  $j \in \mathcal{J}$  a score  $\sigma_j = |\bar{x}_j^{k-1} - \tilde{x}_j^k|$ , also known as fractionality, and the  $p$  components of  $\tilde{x}^k$  with highest score are the ones whose value is flipped. For example, consider a binary variable  $x_j$ , with  $\bar{x}_j^{k-1} = 0.5$  and  $\tilde{x}_j^k = 1$ . By flipping the value of  $\tilde{x}_j^k$  to 0, the distance  $\Delta^{\mathcal{J}}(\bar{x}^{k-1}, \tilde{x}^k)$  does not increase. Pseudocode for the perturbation procedure can be found in Algorithm 1.4 (lines 12-16).

If at any iteration  $\tilde{x}^k$  is the same as  $\tilde{x}^l$  for some  $l \in \{1, \dots, k-2\}$ , then a “major” perturbation, also known as *restart*, is applied (line 18 of Algorithm 1.4). Pseudocode of the restart mechanism is presented separately in Algorithm 1.3. The restart procedure takes as input the current integer vector  $\tilde{x}^k$ , the LP-feasible vector  $\bar{x}^{k-1}$  obtained in the previous pumping iteration, the set of indices  $\mathcal{J}$ , which is equal to  $\mathcal{B}$  in Stage 1, and equal to  $\mathcal{B} \cup \mathcal{G}$  in Stage 2, and the parameter *avgPert*. In contrast to the previous perturbation procedure, during a restart binary and integer variables are treated differently, and in most cases more integer components of  $\tilde{x}^k$  change value. For each  $j \in \mathcal{B}$ , a uniformly random number  $\rho_j \in [-0.3, 0.7]$  is generated and the value  $\tilde{x}_j^k$  is flipped to the opposite bound if  $\sigma_j + \max\{\rho_j, 0\} > 0.5$ . The restart procedure is designed to flip more frequently binary components of  $\tilde{x}^k$  with large fractionality, since again, larger values of  $\sigma_j$ , yield smaller increase in  $\Delta^{\mathcal{J}}(\bar{x}^{k-1}, \tilde{x}^k)$ .

The procedure gets more complex in Stage 2. Flipping the value of an integer component  $\tilde{x}_j^k, j \in \mathcal{G}$  to either  $\lfloor \bar{x}_j^{k-1} \rfloor$  or  $\lceil \bar{x}_j^{k-1} \rceil$  based on the previously defined score, seems to not be that helpful in escaping cycles with length longer than one. Even if FP does escape the cycle, in many cases a new cycle occurs again in the next few iterations. A possible explanation for this behavior is that the previously explained restart mechanism does not consider all possible values from the domains of general integer variables, but only the two closest integer values to the corresponding components of  $\bar{x}^{k-1}$ . In Algorithm 1.3 the parameter *maxFlips* contains the maximum number of general integer components of  $\tilde{x}^k$  whose value is going to change. This number is chosen in a conservative way, since changing  $\tilde{x}^k$  too much, introduces a large amount of randomness in FP, i.e., large oscillations in the projection step objective, and therefore might lead to unsuccessful termination of FP. More precisely, *maxFlips* is set to  $\max\{\frac{|\mathcal{G}|}{10}, \text{minChange}\}$ , where *minChange* is a small fixed number, e.g., Bertacco et al. [4] fix *minChange* to 10. The actual number of components that change value is denoted by *RP* and depends on the frequency of restarts during the course of FP. Initially, *RP* is set to the minimum of a randomly generated integer from  $[\frac{\text{avgPert}}{2}, \frac{3 \cdot \text{avgPert}}{2}]$  and *maxFlips*. For each pumping iteration without a restart, *RP* is reduced geometrically by a factor 0.85, and when a restart occurs it is increased by a linear factor, i.e., *RP* is increased



by  $2 \cdot \text{avgFlips} + 1$ . The goal of this is to apply a more aggressive restart the more frequently FP cycles. Next, a subset  $\text{toFlip} \subseteq \mathcal{G}$  of  $RP$  indices of integers is randomly chosen. For each  $j \in \text{toFlip}$ , if the size of the domain of variable  $x_j$  is less than  $MM = 10^{15}$ , the new value of  $\tilde{x}^k$  is set equal to a random value within its domain. More precisely, in this case we set  $\tilde{x}^k$  to  $\lfloor l_j + (1 + u_j - l_j)r_j \rfloor$ , where  $r_j$  is a uniformly random variable from  $[0, 1)$ . Note that in practice only unbounded integer variables have domains with size larger than  $MM$ . In this case, if  $\tilde{x}_j^k$  is sufficiently close to one of its bounds, i.e.,  $\tilde{x}_j^k - l_j < M$  or  $u_j - \tilde{x}_j^k < M$  for  $M = 10^9$ , then its new value is picked randomly within a large neighborhood around its closest bound. In particular, if  $\tilde{x}_j^k - l_j < M$ , then the new value of  $\tilde{x}_j^k$  is set to  $l_j + \lfloor (2M - 1)r_j \rfloor$ , and if  $u_j - \tilde{x}_j^k < M$ , its new value is set to  $u_j - \lfloor (2M - 1)r_j \rfloor$ . Finally, if none of the previous conditions is true, the new value is picked randomly within a large neighborhood around  $\tilde{x}_j^k$ . In this case  $\tilde{x}_j^k$  is set to  $\tilde{x}_j^k + \lfloor (2M - 1)r_j \rfloor - M$ . Lastly, line 24 ensures that the new value of  $\tilde{x}_j^k$  lies within its domain.

**Algorithm 1.3:** Restart Procedure

---

```

Input      : integer vector  $\tilde{x}^k$ , vector  $\bar{x}^{k-1}$ ,  $\mathcal{J} \in \{\mathcal{B}, \mathcal{B} \cup \mathcal{G}\}$ ,
                $avgPert \in \mathbb{N}$ 
Parameters:  $M = 10^9$ ,  $MM = 10^{15}$ 
Output    : Perturbed vector  $\tilde{x}^k$ 
1 for  $j \in \mathcal{B}$  do                                     /* Applies in Stage 1 and 2 */
2   Generate  $\rho_j \in [-0.3, 0.7]$ 
3   Compute score  $\sigma_j = |\bar{x}_j^{k-1} - \tilde{x}_j^k|$ 
4   if  $\sigma_j + \max\{\rho_j, 0\} > 0.5$  then
5     Flip  $\tilde{x}_j^k$  to the other bound
6 if  $\mathcal{G} \in \mathcal{J}$  then                                 /* Applies in Stage 2 */
7    $maxFlips \leftarrow \max\{|\mathcal{G}|/10, minChange\}$ 
8    $RP \leftarrow rndInt(avgPert/2, 3 \cdot avgPert/2)$ 
9    $iterNoRest \leftarrow$  number of iterations since last restart
10   $RP \leftarrow RP \cdot 0.85^{iterNoRest}$                 /* geometric decrease */
11   $RP \leftarrow RP + 2 \cdot avgFlips + 1$                 /* linear increase */
12   $RP \leftarrow \min\{RP, maxFlips\}$ 
13   $toFlip \leftarrow$  pick  $RP$  random indices from  $\mathcal{G}$ 
14 for  $j \in toFlip$  do
15   Generate  $r_j \in [0, 1)$ 
16   if  $u_j - l_j < MM$  then
17      $newValue \leftarrow \lfloor l_j + (1 + u_j - l_j)r_j \rfloor$ 
18   else if  $\tilde{x}_j^k - l_j < M$  then
19      $newValue \leftarrow l_j + \lfloor (2M - 1)r_j \rfloor$ 
20   else if  $u_j - \tilde{x}_j^k < M$  then
21      $newValue \leftarrow u_j - \lfloor (2M - 1)r_j \rfloor$ 
22   else
23      $newValue \leftarrow \tilde{x}_j^k + \lfloor (2M - 1)r_j \rfloor - M$ 
24    $\tilde{x}_j^k \leftarrow \max\{\min\{newValue, u_j\}, l_j\}$ 
25 return  $\tilde{x}^k$ 

```

---

**Termination Criteria**

Since the goal of FP is to quickly find a feasible solution, upper bounds on the number of iterations in Stage 1 and Stage 2 are set. Further, if the distance of the two sequences  $\{\bar{x}^k\}_{k=1}^K$  and  $\{\tilde{x}^k\}_{k=1}^K$  w.r.t. the set of integer variable indices  $\mathcal{J}$  does not decrease sufficiently, i.e., does not decrease by at least 10%, for a given number of iterations in the current stage, the algorithm continues with the next stage. Lastly, as already seen, frequent restarts are often an indicator that FP

may fail to converge to a feasible solution. Hence, if a maximal number of restarts is applied in the current stage, then again FP continues with the next stage. The parameters  $(maxIterS1, maxIterNoImprS1, maxRestS1)$  and  $(maxIterS2, maxIterNoImprS2, maxRestS2)$  in Algorithm 1.2 denote the maximum numbers of: iterations, iterations without a 10% improvement, and restarts in Stage 1 and Stage 2, respectively.

### Pumping Loop

To summarize, Algorithm 1.4 gives a detailed description of the pumping loop used by FP (Algorithm 1.2). The pumping loop is initialized with the MIP  $P$ , and depending on the stage, a set of indices  $\mathcal{J} \subseteq \mathcal{I}$ , termination parameters, and the parameter  $avgPert$ , which is used in the perturbation step. Once again,  $\mathcal{J} = \mathcal{B}$  in Stage 1, and  $\mathcal{J} = \mathcal{I}$  in Stage 2. The termination parameters  $maxIter$ ,  $maxIterNoImpr$ ,  $maxRest$  are equal to  $maxIterS1$ ,  $maxIterNoImprS1$ ,  $maxRestS1$  in Stage 1, and equal to  $maxIterS2$ ,  $maxIterNoImprS2$ ,  $maxRestS2$  in Stage 2. In the main loop we keep track of all found integer vectors by adding them in the list  $listIntegers$ . Note that the current integer vector is always pushed in front of the list (line 22). Moreover, the variable  $closestDist \in \mathbb{R}$  keeps track of the smallest value  $\Delta^{\mathcal{J}}(\bar{x}^k, \tilde{x}^k)$  and  $closestInt \in \mathbb{R}^n$  is the integer vector for which the value  $closestDist$  is attained. In each iteration  $k$  of the main loop (lines 6-32), if the vector  $\bar{x}^{k-1}$  is integer w.r.t. the index set  $\mathcal{J}$ , a solution for the current stage is found and the pumping loop terminates. Otherwise,  $\bar{x}^{k-1}$  is rounded to  $\tilde{x}^k$  by using a perturbed rounding procedure (line 11) as explained previously. If  $\tilde{x}^k$  is equal to the first element of  $listIntegers$ , i.e.,  $\tilde{x}^k = \bar{x}^{k-1}$ , then  $p$  components of  $\tilde{x}^k$  are perturbed. Next, as long as  $\tilde{x}^k$  is contained in  $listIntegers$  and the maximal number of restarts  $maxRest$  is not reached, the restart mechanism described in Algorithm 1.3 is called in line 18. If  $maxRest$  is reached and  $\tilde{x}^k$  is still contained in  $listIntegers$ , the pumping loop terminates and returns the integer vector  $closestInt$ . Otherwise,  $\tilde{x}^k$  is pushed in front of  $listIntegers$ , the projection step is called, and the loop continues with the next iteration. The pumping loop terminates after at most  $maxIter$  iterations or after  $maxIterNoImpr$  iterations without a 10% decrease of  $closestDist$ . In case of an unsuccessful termination it returns the vector  $closestInt$ .

**Algorithm 1.4:** Pumping Loop

---

**Input** : A MIP  $P$  in the form (1.1),  $\mathcal{J} \subseteq \mathcal{I}$ ,  $\bar{x}^0 \in \mathbb{R}^n$   
**Parameters:**  $maxIter$ ,  $maxIterNoImpr$ ,  $maxRest$ ,  $avgPert \in \mathbb{N}$   
**Output** : Integer vector w.r.t.  $\mathcal{J}$

---

```

1  $k \leftarrow 0$ 
2  $iterNoImpr \leftarrow 0$ 
3  $nRest \leftarrow 0$ 
4  $listIntegers \leftarrow []$ 
5  $closestDist \leftarrow +\infty$ 
6 while  $k < maxIter$  and  $iterNoImpr < maxIterNoImpr$  do
7    $k \leftarrow k + 1$ 
8   if  $\bar{x}_j^{k-1} \in \mathbb{Z}$  for all  $j \in \mathcal{J}$  then
9      $\text{return } \bar{x}^{k-1}$ 
10  Generate  $\tau \in [0, 1)$ 
11   $\tilde{x}^k \leftarrow \lfloor \bar{x}^{k-1} + \tau \rfloor^{\mathcal{J}}$  /* Rounding step */
12  if  $\tilde{x}^k = listIntegers[0]$  then /* Perturb */
13     $p \leftarrow randInt(avgPert/2, 3 \cdot avgPert/2)$ 
14    for  $j \in \mathcal{J}$  do
15       $\lfloor$  Compute score  $\sigma_j = |\bar{x}_j^{k-1} - \tilde{x}_j^k|$ 
16       $\lfloor$  Flip  $p$  values  $\tilde{x}_j^k$  with largest  $\sigma_j$  to the other bound
17  while  $\tilde{x}^k \in listIntegers$  and  $nRest < maxRest$  do /* Restart */
18     $\tilde{x}^k \leftarrow restart(\tilde{x}^k, \bar{x}^{k-1}, \mathcal{J}, avgPert)$ 
19     $nRest \leftarrow nRest + 1$ 
20  if  $\tilde{x}^k \in listIntegers$  then /* maxRest reached */
21     $\text{return } closestInt$ 
22   $listIntegers.push\_front(\tilde{x}^k)$ 
23   $\bar{x}^k \leftarrow \arg \min\{\Delta^{\mathcal{J}}(x, \tilde{x}^k) : x \in P_{LP}\}$  /* Projection step */
24  if  $\Delta^{\mathcal{J}}(\bar{x}^k, \tilde{x}^k) \leq closestDist$  then
25    if  $\Delta^{\mathcal{J}}(\bar{x}^k, \tilde{x}^k) \leq 0.9 \cdot closestDist$  then
26       $\lfloor$   $iterNoImpr \leftarrow 0$ 
27    else
28       $\lfloor$   $iterNoImpr \leftarrow iterNoImpr + 1$ 
29       $closestDist \leftarrow \Delta^{\mathcal{J}}(\bar{x}^k, \tilde{x}^k)$ 
30       $closestInt \leftarrow \tilde{x}^k$ 
31  else
32     $\lfloor$   $iterNoImpr \leftarrow iterNoImpr + 1$ 
33 return  $closestInt$ 

```

---

## Strategies to Improve the Solution Quality

This version of FP considers the original objective  $c^\top x$  of the MIP  $P$  only in the initialization phase. Thus, since in each pumping iteration the vectors  $\bar{x}^k$  and  $\tilde{x}^k$  are obtained by operations that do not consider the original objective function  $c^\top x$ , the objective value of the final solution is in many cases of low quality. The authors of [29, 4] suggested two strategies to improve the solution quality. In the first strategy, when a feasible solution is found, instead of terminating, an artificial constraint is added in the projection step that cuts-off the feasible solution. In particular, the additional constraint bounds the original objective  $c^\top x$  by a convex combination of the objective value of the optimal solution of the LP relaxation  $\bar{x}^0$ , and the objective value of the best quality feasible solution  $\tilde{x}^{best}$  found so far,

$$c^\top x \leq \beta c^\top \bar{x}^0 + (1 - \beta) c^\top \tilde{x}^{best}, \beta \in (0, 1). \quad (1.11)$$

For example, when a feasible solution  $\tilde{x}^*$  is found, then the constraint

$$c^\top x \leq \beta c^\top \bar{x}^0 + (1 - \beta) c^\top \tilde{x}^* \quad (1.12)$$

cuts-off  $\tilde{x}^*$  in case  $c^\top \tilde{x}^* > c^\top \bar{x}^0$ , since

$$c^\top \tilde{x}^* > \beta c^\top \bar{x}^0 + (1 - \beta) c^\top \tilde{x}^*.$$

Note that for the case where  $c^\top \tilde{x}^* = c^\top \bar{x}^0$ , then, obviously,  $\tilde{x}^*$  is an optimal feasible solution and (1.12) is fulfilled with equality. Finally, FP terminates after a termination criterion is met and returns the best quality feasible solution that was found. In the second strategy, when FP terminates with a feasible solution, an improvement heuristic such as RINS [19] or a local branching heuristic [26] is applied with the aim of obtaining some feasible solution with better quality. In Chapter 2, we discuss an additional strategy to obtain better quality solutions that makes use of the original objective of the MIP directly in the projection step of FP.

## 1.5. Outline

The remainder of this thesis is structured as follows: In Chapter 2 we discuss two of the most cited modification of FP which are also part of our implementation. Those are the *Objective Feasibility Pump* (OFP) introduced by Achterberg and Berthold [1], and the *Feasibility Pump 2.0* (FP2.0) from Fischetti and Salvagnin [27]. In Chapter 3 we provide a literature review of alternative interpretations of FP, various modifications for the rounding, perturbation, and projection steps, and also algorithms that employ FP. In Chapter 4 we present various extensions of FP, which consider multiple integer reference vectors in the projection step instead of a single one, and also alternative objective scalings for OFP. Next, we extend

the idea of using multiple integer reference vector in the objective function of the MIP in Stage 3. Moreover, we introduce a technique, which we call *mRENS*, that uses LP-feasible vectors obtained during the pumping loop to tighten the domains of integer variables in Stage 3. In Chapter 5 we present details regarding our implementation, the setup of our computational experiments, and the test set of MIP instances that we use. Next, in Chapter 6 we report on the results of our computations. Finally, in Chapter 7, we wrap-up with a short summary and an outlook of further interesting research directions.

## Objective Feasibility Pump 2.0

In this chapter we discuss the two most cited modifications of FP [1, 27] which are also used in the freely available FP solver at the Neos server [18]. The version of FP incorporating both modifications is called *Objective Feasibility Pump 2.0*, or shortly OFP2, and will be considered as the baseline FP algorithm in later chapters of the thesis. Throughout this chapter, we consider a MIP in the form (1.1) and a set  $\mathcal{J} \subseteq \mathcal{I}$ , which contains the indices of integers variables in the current FP stage. The current pumping iteration of FP is denoted by  $k$ .

### 2.1. Objective Feasibility Pump

As already mentioned, FP considers the original objective  $c^\top x$  of the MIP only in the initialization phase, which often results in finding solutions of poor quality. In Chapter 1 we discussed two strategies to address this issue. When FP finds a feasible solution  $\tilde{x}^*$ , the first strategy adds an artificial constraint that cuts-off  $\tilde{x}^*$  and bounds the original objective  $c^\top x$  in a way that only solutions with better quality remain feasible. The second strategy applies improvement heuristics, such as RINS or local branching, after a successful run of FP. Achterberg and Berthold [1] proposed a slightly modified version of FP, called *Objective Feasibility Pump* (OFP), which considers also the original objective function  $c^\top x$  in the projection step. More precise, they replace the objective function of the projection step by a convex combination of the  $L_1$ -distance to the current integer vector  $\tilde{x}^k$  and a term considering the original objective function of the MIP  $c^\top x$ , i.e.,

$$\Delta_{\alpha_k}^{\mathcal{J}}(x, \tilde{x}^k) := (1 - \alpha_k)\Delta^{\mathcal{J}}(x, \tilde{x}^k) + \frac{\alpha_k \|\Delta^{\mathcal{J}}\|_2}{\|c\|_2} c^\top x, \quad (2.1)$$

with  $\alpha_k \in [0, 1]$ . In the first pumping iteration,  $\alpha_1$  takes a value from  $[0, 1]$  and in subsequent iteration its value is decreased by a fixed factor  $\phi \in (0, 1)$ , i.e.,  $\alpha_{k+1} = \phi \alpha_k$ .

The goal of OFP is to dynamically adjust the influence of  $\Delta^{\mathcal{J}}(x, \tilde{x}^k)$  and  $c^\top x$  in the projection step objective. In early iterations of the pumping loop, the projection step prioritizes solutions with good quality over feasibility, and gradually, the priority of feasibility over solution quality is increased. After  $\alpha_k$  reaches a small threshold value, e.g.,  $\alpha_k < 10^{-4}$ , it is set to 0 in all subsequent iterations. Thus,  $\Delta_{\alpha_k}^{\mathcal{J}}(x, \tilde{x}^k)$  is equal to the original projection objective  $\Delta^{\mathcal{J}}(x, \tilde{x}^k)$ . The aim of the Euclidean norms  $\|\Delta^{\mathcal{J}}\|_2$  and  $\|c\|_2$  is to bring the terms  $\Delta^{\mathcal{J}}(x, \tilde{x}^k)$  and  $c^\top x$  on the same scale. Note that  $\|\Delta^{\mathcal{J}}\|_2$  is the Euclidean norm of the objective function vector in (1.10) and is equal to  $\sqrt{|\mathcal{J}|}$ . Moreover, for  $\alpha_1 = 0$ , OFP is the same as FP.

Moreover, OFP incorporates an adjustment in the restart mechanism. During the first iterations, it may occur that OFP cycles more often than FP, due to the fact that for large values of  $a_k$  the distance function  $\Delta^{\mathcal{J}}(x, \tilde{x}^k)$  has a small influence on the objective function (2.1). Thus, similar LP solutions may be revisited, which are then often rounded to previously obtained integer vectors. However, revisiting integer vectors, does not necessarily mean that the algorithm stalls. For example, if the current integer vector  $\tilde{x}^k$  is equal to  $\tilde{x}^l$  with  $l \in \{1, \dots, k-2\}$ , it holds that  $\Delta_{\alpha_k}^{\mathcal{J}}(x, \tilde{x}^k)$  is different from  $\Delta_{\alpha_l}^{\mathcal{J}}(x, \tilde{x}^l)$ , if  $\alpha_k \neq \alpha_l$ . Therefore, the projection step solution  $\bar{x}^k$  is not necessarily equal to  $\bar{x}^l$ , which means that OFP may not cycle, or even if it does, the cycle may be escaped in a subsequent iteration, since the parameter  $\alpha_k$  is dynamically adjusted. Consequently, the authors propose to apply the restart procedure only if  $\alpha_l - \alpha_k \leq \delta$  with  $\delta \in [0, 1]$  being a fixed threshold parameter.

The computational experiments in [1] were conducted with  $\alpha_1 = 0.9$ ,  $\phi = 0.9$ , and  $\delta = 0.005$  and show that OFP could find solutions with considerably better quality than FP with a moderate increase of the running time.

## 2.2. Feasibility Pump 2.0

Recall that the integer vector  $\tilde{x}^k$  in the current iteration is computed by

$$\tilde{x}^k = \lfloor \bar{x}^{k-1} + \tau \rfloor^{\mathcal{J}},$$

with  $\tau \in [0, 1)$ . Note that this rounding procedure does not consider the linear constraints of the MIP. Therefore,  $\tilde{x}^k$  may violate a large number of constraints which could lead to many pumping iterations and unsuccessful termination. Fischetti and Salvagnin [27] introduced the Feasibility Pump 2.0 (FP2.0), which integrates techniques from constraint programming in the rounding step of FP.

### Excursion: Constraint Programming and Propagation

Constraint programming is a computational paradigm for finding feasible solutions for problems that are modelled in terms of arbitrary variable domains and constraints.



**Definition 2.1.** (*constraint program*) Let  $m, n \in \mathbb{Z}_{\geq 0}$ . A constraint program (CP) is defined as a triple  $CP = (\mathcal{C}, D, f)$  with  $D = D_1 \times \cdots \times D_n \subseteq \mathbb{R}^n$ ,  $\mathcal{C} = \{C_1, \dots, C_m\}$  being a finite set of constraints  $C_i : D \mapsto \{0, 1\}$ ,  $i \in \{1, \dots, m\}$ , and an objective function  $f : D \mapsto \mathbb{R}$ , and consists in solving

$$f^* = \min_{x \in \mathbb{R}^n} \{f(x) \mid x \in D, C_i(x) = 1 \text{ for all } i \in \{1, \dots, m\}\} \quad (\text{CP})$$

Each constraint  $C \in \mathcal{C}$  is associated with a set  $\text{vars}(C) \subseteq \{1, \dots, n\}$ , which contains the indices of variables that are involved in the constraint.

Note that any MIP is a CP with integer and real-valued domains, linear constraints, and a linear objective function. In particular, consider a MIP in the form (1.1). For each variable  $x_j$  with  $j \in \{1, \dots, n\}$  we define its domain  $D_j$  as the set of all possible values it can take, i.e.,  $D_j = [l_j, u_j]$  for  $j \in \{1, \dots, n\} \setminus \mathcal{I}$  and  $D_j = [l_j, u_j] \cap \mathbb{Z}$  for  $j \in \mathcal{I}$ . For each  $i \in \{1, \dots, m\}$  we define  $C_i : D \mapsto \{0, 1\}$  as

$$C_i(x) = \begin{cases} 1, & \text{if } a_i^\top x \leq b_i \\ 0, & \text{otherwise,} \end{cases}$$

where  $a_i \in \mathbb{R}^n$  is the vector of coefficients of the  $i$ -th row of the constraint matrix  $A$ . Finally, the objective function  $f : D \mapsto \mathbb{R}$  is given by  $f(x) = c^\top x$ . In the following, when we mention a linear constraint  $C_i \in \mathcal{C}$ , we simply refer to the inequality  $a_i^\top x \leq b_i$ .

One of the core components of constraint programming solvers are propagation engines. A propagation engine can be seen as a fixed point algorithm that takes as input the domain  $D$  of the variables and uses the constraints to remove values from  $D$  that cannot belong to any solution, until no more values can be removed.

A *propagator* for a constraint  $C \in \mathcal{C}$  is a mapping  $p : D \mapsto D$  that removes values from  $D$ , that cannot belong to any feasible solution. In general, each constraint can be associated with multiple propagators. As mentioned by Fischetti and Salvagnin [27], propagators must fulfill some important properties. Firstly, propagators cannot add values in the domain, i.e.,  $p(D) \subseteq D$ , and can only remove values that cannot belong to any feasible solution. Secondly, for two domains  $\tilde{D}$  and  $\bar{D}$  with  $\tilde{D} \subseteq \bar{D}$ , it must hold that  $p(\tilde{D}) \subseteq p(\bar{D})$ . Lastly, if for all  $x \in D$ , it holds that  $C(x) = 1$ , then  $D$  is a fixpoint of  $p$ , i.e.,  $p(D) = D$ . We denote by  $\text{vars}(p) \subseteq \{1, \dots, n\}$  the indices of variables that are involved in the corresponding constraint  $C$ .

Algorithm 2.1 gives a basic scheme of a propagation engine, as explained by Fischetti and Salvagnin [27]. The algorithm takes as input a domain  $D$ , a set of propagators  $F$  with a fixpoint at  $D$ , and a set of propagators  $NF$  that do not have a fixpoint at  $D$ . The algorithm maintains a queue of non-fixpoint propagators, which is initially  $Q = NF$ . In each iteration of the main loop a propagator  $p$  is extracted from  $Q$ , and the domain  $D$  is set to  $p(D)$ . The set  $I$  contains the indices of variables whose domain was changed, and  $Q$  is updated to the set all

propagators  $q \in F \cup NF$  with  $\text{vars}(q) \cap I \neq \emptyset$ . The algorithm terminates when  $Q$  is empty and returns the updated domain  $D$ .

---

**Algorithm 2.1:** Domain Propagation

---

**Input** : Domain  $D$ , fixpoint propagators  $F$ , non-fixpoint propagators  $NF$

**Output** : new domain  $D$

- 1  $Q \leftarrow NF$
- 2 **while**  $Q$  not empty **do**
- 3      $p \leftarrow Q.\text{pop}()$
- 4      $D \leftarrow p(D)$
- 5      $I \leftarrow$  indices of variables whose domain changed
- 6      $Q \leftarrow Q \cup \{q \in F \cup NF : \text{vars}(q) \cap I \neq \emptyset\}$
- 7 **return**  $D$

---

### Domain Propagation in the Feasibility Pump

Many techniques used in constraint programming, such as domain propagation, can also be used for MIP. Again, consider a MIP in the form (1.1) with variable domains  $D$ , and linear constraints  $\mathcal{C}$  as above. A commonly used propagator for linear constraint is based on the so-called bound strengthening technique introduced by Brearley et al. [16]. Details for bound strengthening can be also founded in [27, 48]. Given a linear constraint  $a_i^\top x \leq b_i$ ,  $i \in \{1, \dots, m\}$ , a bound strengthening-based linear propagator tries to infer tighter bounds for variables with nonzero coefficients in  $a_i^\top x \leq b_i$ . At first, the smallest and largest possible values of  $a_i^\top x$  with  $x \in D$  are computed, and are denoted by  $a_i^{\min}$  and  $a_i^{\max}$ , respectively. For any  $j \in \{1, \dots, n\}$  with  $a_{ij} > 0$ , it holds that

$$a_i^{\min} + a_{ij}(x_j - l_j) \leq a_i^\top x \leq b_i \Leftrightarrow x_j \leq l_j + \frac{b_i - a_i^{\min}}{a_{ij}} =: u_j^{\text{new}}.$$

Hence, if  $u_j^{\text{new}}$  is smaller than the upper bound  $u_j$ , we can set  $u_j = u_j^{\text{new}}$ . Moreover, if  $x_j$  is an integer variable, we set  $u_j = \lfloor u_j^{\text{new}} \rfloor$ . With a similar argument, tighter lower bounds can be inferred for variables  $x_j$  with  $j \in \{1, \dots, n\}$  and  $a_{ij} < 0$ .

Finally, we can describe the rounding procedure used in FP2.0. Let  $\mathcal{J}$  be the index set of integer variables in the current stage of FP. For any  $j \in \mathcal{J}$ , the rounded value  $\tilde{x}_j^k$  can be seen as a temporary fixing of the variable  $x_j$  at the value  $\tilde{x}_j^k$ , or equivalently, as setting  $D_j = \{\tilde{x}_j^k\}$ . After fixing the domain of a variable, a propagation engine can be used to tighten the domain of non-fixed variables. More precisely, Algorithm 2.2 takes as input a domain  $D$ , a fractional vector  $\bar{x} \in D$ , a set of indices of integer variables  $\mathcal{J}$ , and a set of propagators for the linear constraints  $R$ . The main loop maintains an index set of non-fixed integer variables  $\tilde{\mathcal{J}} \subseteq \mathcal{J}$ . In each iteration of the main loop, the algorithm picks an index  $j \in \tilde{\mathcal{J}}$  of a non-fixed variable  $x_j$ , i.e., a variable  $x_j$  with  $|D_j| > 1$ . Since the domain

of the variables may change during propagation, it may happen that  $\bar{x}_j$  does not lie in  $D_j$ . If  $\bar{x}_j$  is less than  $l_j$ , then  $D_j$  is set to the singleton  $\{l_j\}$ . Analogously, if  $\bar{x}_j$  is greater than the upper bound  $u_j$ ,  $D_j$  is set to  $\{u_j\}$ . In any other case,  $D_j$  is set to the singleton that contains the rounding  $\lfloor \bar{x}_j + \tau \rfloor$ . Next, after fixing  $D_j$  to a singleton, the propagation engine is called to update the whole domain  $D$ . The set of non-fixed variables  $\tilde{\mathcal{J}}$  is updated and the algorithm proceeds with the next iteration. The algorithm terminates when all integer variables are fixed to a value, i.e., the domain of each integer variable is a singleton. The final output is an integer vector  $\tilde{x}$ , which is constructed as follows. For any  $j \in \mathcal{J}$ ,  $\tilde{x}_j$  is set to the value of the single element of  $D_j$ , otherwise  $\tilde{x}_j = \bar{x}_j$ .

It is important to mention that a constraint propagation engine tries to detect infeasibility of the problem as soon as possible. However, in FP we need to set all integer variables at a value. Therefore, propagators that lead to empty domains of integer variables are removed from  $R$  and the algorithm continues until all integer variables are fixed. For the sake of efficiency, the authors make use of specialized propagators for different types of linear constraints. For more details about optimizing the performance of Algorithm 2.2 and its complexity we refer to [27].

Note that OFP and FP2.0 can be combined and as already mentioned the algorithm is called *Objective Feasibility Pump 2.0* (OFP2). The computational experiments in [27] show that OFP2 outperforms (O)FP for both 0-1 and general integer MIPs in terms of solution quality, number of iterations, and running time. Moreover, OFP2 was able to find feasible solutions for many instances where (O)FP failed.

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**Algorithm 2.2:** PropRound
 

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**Input** : A domain  $D$ , a fractional vector  $\bar{x}$ , indices of integers  $\mathcal{J}$ ,  
 set of propagators  $R$   
**Output** : integer vector  $\tilde{x}$

- 1 Generate  $\tau \in [0, 1)$
- 2  $\tilde{\mathcal{J}} \leftarrow \{i \in \mathcal{J} \mid |D_i| > 1\}$  /\* Non-fixed variables \*/
- 3 **while**  $\tilde{\mathcal{J}}$  not empty **do** /\* PropRound loop \*/
- 4     choose  $j \in \tilde{\mathcal{J}}$
- 5     **if**  $\bar{x}_j \leq l_j$  **then**
- 6          $D_j \leftarrow \{l_j\}$
- 7     **if**  $\bar{x}_j \geq u_j$  **then**
- 8          $D_j \leftarrow \{u_j\}$
- 9     **else**
- 10          $D_j \leftarrow \{\lfloor \bar{x}_j + \tau \rfloor\}$
- 11      $D \leftarrow \text{propagate}(D, R)$
- 12      $\tilde{\mathcal{J}} \leftarrow \{i \in \tilde{\mathcal{J}} \mid |D_i| > 1\}$
- 13 **for**  $j \in \mathcal{J}$  **do** /\* Construct  $\tilde{x}$  \*/
- 14      $\tilde{x}_j \leftarrow$  single element of  $D_j$
- 15 **for**  $j \notin \mathcal{J}$  **do**
- 16      $\tilde{x}_j \leftarrow \bar{x}_j$
- 17 **return**  $\tilde{x}$

---

## Literature Review

In this chapter we give an overview of literature regarding FP. A recent overview can be found also in the work of Berthold et al. [9]. In the first section, we discuss theoretical properties and alternative interpretations of FP. In later sections we review various modifications for the rounding and perturbation step, and algorithms that are build around FP. Throughout this chapter, we consider a MIP in the form (1.1) and a set  $\mathcal{J} \subseteq \mathcal{I}$ , which contains the indices of integer variables in the current FP stage. The current iteration of FP is always denoted by  $k$ .

### 3.1. Interpretations of the Feasibility Pump

As already seen, the goal of primal heuristics is to find feasible solutions for MIPs in a short amount of time. However, their theoretical properties, if any, are rarely known. Thanks to a remark in the work of Eckstein and Nediak [24] some interesting theoretical properties and alternative interpretations of FP have been stated. In the following, (O)FP using the nearest rounding and without any random perturbations is called *idealized* (O)FP.

#### FP as Frank-Wolfe Algorithm

The authors of [24] noticed that for 0-1 MIPs the idealized FP is equivalent to applying the Frank-Wolfe algorithm [30] to a minimization problem with a separable non-smooth concave merit function  $f : \mathbb{R}^n \rightarrow \mathbb{R}$  in the objective. Indeed, for 0-1 MIPs the  $k$ -th iteration of the idealized FP is equivalent to solving the optimization problem

$$\begin{aligned} \min_x \quad & \sum_{\substack{j \in \mathcal{J}: \\ \bar{x}_j^{k-1} < \frac{1}{2}}} x_j - \sum_{\substack{j \in \mathcal{J}: \\ \bar{x}_j^{k-1} \geq \frac{1}{2}}} x_j \\ \text{s.t.} \quad & x \in P_{\text{LP}}. \end{aligned} \tag{3.1}$$

The coefficient of each variable  $x_j$  in the objective function is an element of the supergradient of the non-smooth concave function  $\phi(t) = \min\{t, 1 - t\}, t \in \mathbb{R}$  at  $\bar{x}_j^{k-1}$ . Therefore, problem (3.1) can be seen as an iteration of the Frank-Wolfe algorithm with unitary stepsize applied to the optimization problem

$$\begin{aligned} \min_x \quad & f(x) := \sum_{j \in \mathcal{J}} \min\{x_j, 1 - x_j\} \\ \text{s.t.} \quad & x \in P_{\text{LP}}. \end{aligned} \tag{3.2}$$

Note, that the objective function of (3.2) is a separable non-smooth concave function, that penalizes the infeasibility of the integrality constraints. The Frank-Wolfe algorithm applied to the given problem terminates after a finite number of iterations and returns a so-called *vertex stationary point*. This is the first theoretical result for FP, that shows that for 0-1 MIPs the idealized FP converges after a finite number of iteration. The perturbation step of FP can be interpreted as a try to escape from noninteger stationary points. Based on this observation, De Santis et al. [20, 21] propose a penalizing system for the objective function of the projection step for measuring solution integrality, firstly for 0-1 MIPs in [20], and afterwards for general integer MIPs in [21].

It is important to note that in each iteration of the Frank-Wolfe algorithm, the objective function strictly decreases, i.e.,  $f(\bar{x}^{k-1}) < f(\bar{x}^k)$ , however the number of integer components with a fractional value in  $\bar{x}^k$  may be larger than in  $\bar{x}^{k-1}$ . In [20] the authors propose to replace the objective function of (3.2), by suitably developed merit functions that guarantee that the objective value decreases whenever the number of integer components with a fractional value also decreases, and if it decreases, the number of integer components with a fractional value does not increase. They introduce four different objective functions  $f : \mathbb{R}^n \rightarrow \mathbb{R}$  for (3.2) that fulfill the previous properties. One of them is

$$f(x) = \sum_{i \in \mathcal{J}} \min\{1 - \exp(-\beta x_j), 1 - \exp(-\beta(1 - x_j))\},$$

with  $\beta > 0$ , which is called *the exponential merit function*. This led to a new version of FP called *Reweighted Feasibility Pump* (RFP), where the  $L_1$ -distance in the objective of the projection step is replaced by the weighted  $L_1$ -distance

$$\begin{aligned} \Delta_{\text{RFP}}^{\mathcal{J}}(x, \tilde{x}^k) &:= \sum_{j \in \mathcal{J}} |w_j^k| |x_j - \tilde{x}_j^k| \\ &= \sum_{\substack{j \in \mathcal{J}: \\ \tilde{x}_j^k = 0}} |w_j^k| x_j + \sum_{\substack{j \in \mathcal{J}: \\ \tilde{x}_j^k = 1}} |w_j^k| (1 - x_j), \end{aligned}$$

where the weights  $w_j^k \in \mathbb{R}$  depend from the choice of the merit function.

Similar results are derived in [21] for MIPs with both binary and general integer variables. However, in this case the analysis is not that straightforward, but

still, by enlarging the variable space it can be shown that the idealized FP is equivalent to applying the Frank-Wolfe algorithm on a minimization problem with a separable non-smooth concave merit function in the objective. Again, similar to the case of 0-1 MIPs, the authors proposed alternative merit functions for the objective that fulfill the same properties as before. In RFP for general integer MIPs the  $L_1$ -distance in the objective of the projection step is replaced by the weighted  $L_1$ -distance

$$\begin{aligned} \Delta_{\text{RFP}}^{\mathcal{J}}(x, \tilde{x}^k) &:= \sum_{j \in \mathcal{J}} |w_j^k| |x_j - \tilde{x}_j^k| \\ &= \sum_{\substack{j \in \mathcal{J}: \\ \tilde{x}_j^k = l_j}} |w_j^k| (x_j - l_j) + \sum_{\substack{j \in \mathcal{J}: \\ \tilde{x}_j^k = u_j}} |w_j^k| (u_j - x_j) + \sum_{\substack{j \in \mathcal{J}: \\ l_j < \tilde{x}_j^k < u_j}} |w_j^k| d_j, \end{aligned} \quad (3.3)$$

where again the weights  $w_j^k \in \mathbb{R}$  depend from the choice of the merit function.

Finally, RFP can be also combined with OFP, by replacing the  $L_1$ -distance in the OFP objective by (3.3). The combination of RFP and OFP is denoted by ORFP. The computational experiments in [21] indicate that ORFP using the exponential merit function is in many cases faster than OFP, and that the quality of the obtained solutions by both methods is comparable.

### Further Interpretations

Boland et al. [10] are able to prove similar convergence results by viewing the idealized OFP as a discrete version of the proximal point algorithm. Moreover, they introduce a cutting plane procedure to prevent cycling which they integrate in OFP2. More specifically, when OFP2 cycles at an integer vector  $\tilde{x}^k$ , a cutting plane procedure is applied at the MIP

$$\begin{aligned} \min_x \quad & \Delta_{\alpha_k}^{\mathcal{J}}(x, \tilde{x}^k) \\ \text{s.t} \quad & x \in P_{\text{MIP}}, \end{aligned} \quad (3.4)$$

and cuts that eliminate the cycle are added in  $P_{\text{LP}}$ . Note that applying a cutting plane algorithm on problem (3.4) is computationally demanding, since it requires solving a series of LPs. Thus, the authors propose to instead use the perturbation procedure of FP with probability  $p = 0.5$ . Finally, if the algorithm fails to escape a cycle for a fixed number of iterations, then the usual restart procedure of OFP2 is used. This version of OFP2 is denoted by FPC. In many cases FPC is able to find better quality solutions than OFP2, however on the cost of increased computational time.

Geißler et al. [32] are able to show similar convergence results by interpreting the idealized FP as an Alternating Direction Method (ADM) applied to a reformulation of the original MIP. Moreover, this interpretation allows the authors to

provide a theoretically analyzable penalty framework for the perturbation step of FP. For the sake of readability, and w.l.o.g., we assume that  $\mathcal{J}$  contains the first  $|\mathcal{J}|$  variable indices, i.e.,  $\mathcal{J} = \{1, \dots, |\mathcal{J}|\}$ . Consider the problem

$$\begin{aligned} \min_{x,y} \quad & \|x_{\mathcal{J}} - y\|_1 \\ \text{s.t.} \quad & x \in P_{\text{LP}} \\ & y_j \in \mathbb{Z} \cap [l_j, u_j] \quad \forall j \in \mathcal{J}, \end{aligned} \tag{3.5}$$

where  $x_{\mathcal{J}} \in \mathbb{R}^{|\mathcal{J}|}$  denotes the vector consisting of the first  $|\mathcal{J}|$  components of  $x \in \mathbb{R}^n$ , and  $y \in \mathbb{R}^{|\mathcal{J}|}$ . Problem (3.5) can be solved by ADM. More precisely, the algorithm is initialized with two vectors  $x^0 \in \mathbb{R}^n$ ,  $y^0 \in \mathbb{R}^{|\mathcal{J}|}$  and in each iteration it computes

$$x^{k+1} \in \arg \min_{x \in \mathbb{R}^n} \{\|x_{\mathcal{J}} - y^k\|_1 \mid x \in P_{\text{LP}}\} \tag{3.6}$$

and

$$y^{k+1} \in \arg \min_{y \in \mathbb{R}^{|\mathcal{J}|}} \{\|x_{\mathcal{J}}^{k+1} - y\|_1 \mid y_j \in \mathbb{Z} \cap [l_j, u_j], \forall j \in \mathcal{J}\} \tag{3.7}$$

It can be easily seen, that applying ADM to (3.5), with  $x^0 = \bar{x}^0$  and  $y^0 = \tilde{x}_{\mathcal{J}}^1$ , is equivalent to solving the original MIP by the idealized FP. Here, (3.6) corresponds to the projection step, and (3.7) to the rounding step. Moreover, the solutions of (3.6), and (3.7) converge at a so-called *partial minimum*  $(x^*, y^*)$  after a finite number of iterations, and obviously, if it holds that  $\|x_{\mathcal{J}}^* - y^*\|_1 = 0$ , then  $x^*$  is a feasible solution for the MIP. Therefore, the perturbation step of FP can be interpreted as an attempt of escaping from noninteger partial minima.

Finally, the authors developed a theoretically analyzable penalty framework that incorporates ADM in its inner loop to replace the perturbation step. In each iteration  $l$  of the penalty framework, ADM is used to obtain a partial minimum  $(x^{l*}, y^{l*})$ . If  $x^{l*}$  is a noninteger vector, then the penalty parameters are updated in order to escape the partial minimum, and the algorithm proceeds with the next iteration. This approach was the first theoretical study of FP incorporating perturbations. Lastly, in a similar way as for FP, an ‘‘objective’’ version of the algorithm was developed that considers  $c^\top x$  in the objective function of (3.6). The computational experiments in [32] show comparable performance to OFP.

## 3.2. Variants of the Rounding Step

Baena and Castro [3] introduced a new variant of FP which is called *Analytic Center Feasibility Pump* (ACFP). In their work the integer vector  $\tilde{x}^k$  at the current pumping iteration is obtained by rounding a vector from the interior of  $P_{\text{LP}}$ , instead of  $\bar{x}^{k-1}$ . Before the execution of the pumping loop the analytic center  $x^{\text{ac}}$  of  $P_{\text{LP}}$  is computed, which is an interior point that maximizes the distance to the boundaries of  $P_{\text{LP}}$ . The analytic center can be computed by interior point



methods, such as the Newton barrier method which was firstly introduced by Karmarkar [38]. In the rounding step, vectors from the line segment connecting  $x^{\text{ac}}$  and  $\bar{x}^{k-1}$  are sampled and are rounded. If some rounded vector is a feasible MIP solution, then ACFP terminates. Otherwise,  $\tilde{x}^k$  is set to the rounded vector minimizing the  $L_\infty$ -distance to the vector of the line segment it has been rounded from. Computational experiments indicate that ACFP combined with the OFP objective is in general inferior to OFP w.r.t. both running time and solution quality. However, for some general integer MIPs, ACFP was able to find more, and better quality solutions.

Naoum-Sawaya [42] proposed a rounding procedure, called *Recursive Central Rounding* (RCP), that can also be integrated in the rounding step of FP. RCP is initialized by a vector  $\bar{x} \in P_{\text{LP}}$ , e.g.,  $\bar{x} = \bar{x}^{k-1}$ . It recursively fixes a subset of integer variables at the corresponding value of the rounding  $\tilde{x}$  of  $\bar{x}$ , and then  $\bar{x}$  is set to the analytic center of the resulting problem. If RCP fails to find a feasible solution for the MIP, one can rearrange the order of variable fixings and restart the recursion. Bear in mind that repeatedly calculating the analytic center is computationally expensive, which makes this method not suitable for instances with many variables and constraints.

As a side remark, we mention the work of Naoum-Sawaya and Elhedhli [43], who developed a rounding heuristic called the *Analytic Center Feasibility Method* (ACFM). In each iteration ACFM rounds vectors from the two line segment connecting the minimizer and maximizer of the LP relaxation of the original MIP to the analytic center  $\bar{x}^{\text{ac}}$ . After each iteration, if no feasible solution is found, cuts are added in  $P_{\text{LP}}$  to shift the position of the analytic center, and the algorithm continues. When an iteration limit is reached an enumeration stage takes places, that solves the original MIP after replacing the objective function by the  $L_1$ -distance to the analytic center  $\bar{x}^{\text{ac}}$  from the first iteration. Note that ACFM is a computationally demanding heuristic, due to the calculation of the analytic center in each iteration. Computational experiments on a test set of small MIP instances, i.e., instances with less than 3000 variables and constraints, showed that ACFM is able to find in many cases better solutions than OFP w.r.t. the solution quality, however the running time is significantly larger.

Boland et al. [11] extend the ideas from [3]. In [3] a fixed number of points on the line segment from  $\bar{x}^{k-1}$  to  $\bar{x}^{\text{ac}}$  are sampled and their roundings are tested for feasibility. Here, the authors use a so-called integer line search that efficiently explores all rounded vectors along a line segment starting at  $\bar{x}^{k-1}$  and ending at  $[\bar{x}^{k-1}] + \bar{d}$ , where  $[\bar{x}^{k-1}]$  is a rounding of  $\bar{x}^{k-1}$  w.r.t. the index set of integer variables  $\mathcal{J}$  and  $\bar{d}$  provides a direction towards feasibility. More precisely,  $\bar{d}$  is a conic combination of all constraints violated by  $[\bar{x}^{k-1}]$ , where each constraint is weighted by the amount of its violation. This endpoint does not necessarily lie in the interior of  $P_{\text{LP}}$ , however it is much more easy to compute than the analytic center, and the computational experiments showed that using  $[\bar{x}^{k-1}] + \bar{d}$  is almost as effective as using  $\bar{x}^{\text{ac}}$  as endpoint. Further, by taking into consideration the

variable bounds, the line segment is extended beyond the endpoints to explore additional, possibly feasible, roundings. The authors integrated the integer line search in OFP2 and the new approach could find solution with considerably better quality at the cost of a moderate increase of the running time.

### 3.3. Variants of the Perturbation Step

Dey et al. [22] showed that for 0-1 MIP instances FP may permanently stall, if the perturbation procedure flips only components of the current integer vector  $\tilde{x}^k$  with fractional value in  $\bar{x}^{k-1}$ . Note, that FP may also flip components with an integer value in  $\bar{x}^{k-1}$ , which may also lead to poor performance and non-convergence. The authors proposed a modified perturbation procedure based on a WALKSAT algorithm [49], where some of the flipping candidates are chosen from the support of constraints violated by  $\tilde{x}^k$ , which is the index set of integer variables with a nonzero coefficient in the violated constraints. It was shown that for a special class of so-called *decomposable 1-row* 0-1 MIP instances, FP converges at a feasible solution and the rate of convergence depends on the degree of decomposability of the problem. The idea was included in OFP2 as follows. Let  $F \subseteq \mathcal{J}$  contain all indices of integer variables  $j \in \mathcal{J}$  with  $\bar{x}_j^{k-1} \notin \mathbb{Z}$ . If  $|F|$  is equal or greater than the maximal number of allowed flips  $p \in \mathbb{N}$ , then the usual perturbation procedure of FP is used. Otherwise, an additional set  $S \subseteq \mathcal{J} \setminus F$  of  $p - |F|$  indices of integer variable is randomly chosen from the support of violated constraints, and the components of  $\tilde{x}^k$  from  $F \cup S$  are flipped. Lastly, it is worth mentioning that the restart mechanism remains unchanged. Computational experiments over 0-1 MIPs that fulfill the convergence conditions showed that incorporating this modification in OFP2 leads to an improvement in terms of success rate, number of iterations, time, and primal gap. Furthermore, when tested on a large heterogeneous test set, the overall performance was slightly better than that of OFP2.

Hanafi et al. [35] introduced a variant of FP for 0-1 MIPs that uses a heuristic called *Variable Neighbourhood Branching* (VNB) in place of the usual perturbation step. When FP detects a cycle at an integer vector  $\tilde{x}^k$ , VNB is used and searches for feasible solutions in the vicinity of  $\tilde{x}^k$ . More specific, each call of VNB iteratively solves the original MIP with an additional constraint  $\Delta^{\mathcal{J}}(x, \tilde{x}^k) \leq r$ , for values  $r > 0$  from an interval  $[r_{\min}, r_{\max}]$ . If an iteration fails to return a feasible solution for the MIP, then the additional constraint is reversed, i.e.,  $\Delta^{\mathcal{J}}(x, \tilde{x}^k) \geq r$ , the value of  $r$  is increased by a step  $r_{\text{step}}$ , and the algorithm continues with the next iteration, until it either finds a feasible solution, or  $r$  reaches the value  $r_{\max}$ . In case of an unsuccessful termination of VNB, an additional constraint is added in the projection step of FP in order to escape the cycle and the pumping loop proceeds.

### 3.4. Further Approaches and Applications

Andrade et al. [2] proposed an evolutionary framework for finding feasible solutions of 0-1 MIPs that exploits information of several FP runs with different initialization vectors. At first, a pool of initialization vectors  $\mathcal{P}$ , also known as population, is generated and contains the optimal solution of the LP relaxation, solutions of the LP relaxation after fixing some variables, and also randomly generated vectors within the variable domains. Each iteration has three phases. In the first phase, FP without any random perturbations is executed for each starting vector from  $\mathcal{P}$  and returns a tuple  $(\bar{x}, \tilde{x}, \Pi)$ , where  $\bar{x}$  and  $\tilde{x}$  are the LP feasible and integer vectors with smallest  $L_1$ -distance found during the pumping loop, and  $\Pi$  is the number of integer variable with a fractional value in  $\bar{x}$ . If no feasible solution is found a so-called evolutionary step is applied where the population  $\mathcal{P}$  is updated by a Biased Random-Key Genetic Algorithm (BRKGA). For a detailed description of BRKGA, see Gonçalves and Resende [34]. The second phase, performs a local search initialized with solution vectors found during phase one with small  $\Pi$ . If still no feasible solution is found, then in the third phase variables that often have the same value in both  $\bar{x}$  and  $\tilde{x}$  are fixed to reduce the problem size, and the algorithm continues with the next iteration. The proposed framework was able to find in many cases feasible solutions for 0-1 MIPs where FP was unsuccessful.

Pradignac et al. [45] proposed an annealing framework for finding feasible solutions of 0-1 MIPs which uses the rounding and projection step of FP in its inner loop. The algorithm is initialized with a pair consisting of an integer vector  $\tilde{x}$  and the solution of the projection step of FP  $\bar{x}$ . Based on this pair, in each iteration new integer vectors are computed by using neighborhood functions, and new fractional vectors by the projection step of FP. If the  $L_1$ -distance between new vectors is smaller than  $\Delta^T(\bar{x}, \tilde{x})$ , or a so-called Metropolis criterion is fulfilled, the pair  $(\bar{x}, \tilde{x})$  is updated. It is important to mention that the perturbation step of FP is deactivated, since randomization is included in the neighborhood functions. In the spirit of simulated annealing algorithms, moving to new pairs with larger fractionality is more probable at the start of the algorithm (diversification), and gradually the probability is decreased (intensification). Further, if a termination criterion is met and no feasible solution is found, the authors propose techniques to fix “hard” integer variables, i.e., variables with a large fractional value in  $\bar{x}$ , and the algorithm is restarted. In many cases the annealing framework was able to find better feasible solutions than FP, especially for hard 0-1 MIP instances.

Huang and Mehrotra [36] proposed a so-called *walk-and-round* framework, that diversifies the search for feasible solutions. The algorithm samples feasible vectors from  $P_{LP}$  with a random walk approach starting near the analytic center. Then, it successively runs FP initialized with those vectors instead of the optimal solution of the LP relaxation. If a run terminates with a feasible solution, a constraint similar to (1.11) is added in the LP relaxation of all subsequent FP runs, which

guarantees that following runs can return only better quality feasible solutions. The results showed that successive runs of FP with different initialization vectors lead to improved quality solutions, however the computational overhead is much larger. It is worth mentioning that for three instances the walk-and-round framework led to improvement of the best known solutions so far.

Koc and Mehrotra [39] conducted a large experiment with parallel subroutines of FP. The FP subroutines are initialized with different random seeds and different feasible vectors from  $P_{LP}$ . In the parallel framework, when a subroutine terminates with a feasible solution, a constraint similar to (1.11) is added in the LP relaxation of all unfinished ones, in order to restrict the search for better quality solutions. Extensive computational experiments indicate that increasing the level of parallelization yields significantly improved quality solutions.

More recently, FP has also gained recognition in reinforcement learning approaches for finding feasible solutions for MIPs. Inspired by FP, Qi et al. [46] proposed a deep reinforcement learning framework called *Smart Feasibility Pump* (SFP), which employs a convolutional neural network structure in place of the projection step of FP. Preliminary test results show that SFP is able to efficiently find feasible solutions for randomly generated small MIP instances with up to 9 variables and 18 constraints.

Lastly, it is worth mentioning, that there exist versions of FP for mixed integer nonlinear programs (see Bonami and Gonçalves [12], Bonami et al. [13, 14], D'Ambrosio et al. [23]), and also many FP-like algorithms are developed for specific problem classes (see for example Bosco et al. [15], Pesneau et al. [44], Requejo and Santos [47]).

## New Ideas for the Feasibility Pump

In the previous chapters, we discussed theoretical aspects and various modifications of FPs core components. As we have seen, at any iteration  $k$  of OFP, the objective function of the projection step is a convex combination of the  $L_1$ -distance to a single integer reference vector  $\tilde{x}^k$  and a term considering the original objective function of the MIP, i.e.,

$$\Delta_{\alpha_k}^{\mathcal{J}}(x, \tilde{x}^k) := (1 - \alpha_k)\Delta^{\mathcal{J}}(x, \tilde{x}^k) + \frac{\alpha_k \|\Delta^{\mathcal{J}}\|_2}{\|c\|_2} c^\top x, \quad (4.1)$$

with  $\alpha_k \in [0, 1]$ . In the first section of this chapter, we propose to exploit information from more than one iteration in the projection step objective. To this end, we suggest a modification of (4.1), which does not only consider a single integer reference vector, but also integer vectors obtained in previous pumping iterations. Moreover, we introduce alternative scaling terms to balance the contributions of  $\Delta^{\mathcal{J}}(x, \tilde{x}^k)$  and  $c^\top x$  in the projection step objective. In the last section, we extend the idea of using multiple reference vectors in Stage 3. Additionally, based on the *relaxation enforced neighborhood search* (RENS) of Berthold [6], we introduce a new primal heuristic which can either be incorporated into Stage 3 or even completely replace it.

Again, throughout this chapter, we consider a MIP  $P$  in the form (1.1) and a set  $\mathcal{J} \subseteq \mathcal{I}$ , which contains the indices of integers variables in the current FP stage. The current pumping iteration is always denoted by  $k$ .

### 4.1. Multiple Reference Vectors in the Projection Step

As already mentioned, the objective function (4.1) considers the  $L_1$ -distance to the integer vector  $\tilde{x}^k$  obtained in the current iteration. From a geometric point of view, the distance function in the projection step objective points towards

a direction that tries to reduce the infeasibility of the integrality constraints of the MIP. For illustration purposes, Figure 4.1 depicts the pointing directions of distance functions used in the first two FP iterations. As we are going to show, using directions in-between, e.g., the dashed lines in Figure 4.1, may also lead to feasible MIP solutions. Motivated by this, we suggest modifications of the distance function in (4.1) by exploiting information from previous iterations.

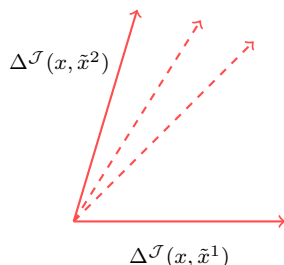


Figure 4.1.: Distance function vectors used in two FP iterations (solid red), and two directions in-between (dashed red).

### Weighted Sum of Distance Functions

Let  $\mathcal{L} = \{1, \dots, k\}$  be the index set of integers vectors obtained during the pumping loop. A conic combination of the  $L_1$ -distances to the integer vectors  $\tilde{x}^i$ ,  $i \in \mathcal{L}$  is defined as

$$\Delta^{\mathcal{J}}(x, \tilde{x}^1, \dots, \tilde{x}^k, \lambda_1, \dots, \lambda_k) := \sum_{i \in \mathcal{L}} \lambda_i \Delta^{\mathcal{J}}(x, \tilde{x}^i), \quad (4.2)$$

where  $\lambda_i \geq 0$  for all  $i \in \mathcal{L}$ . For the sake of readability, we denote the vectors  $\tilde{x}^1, \dots, \tilde{x}^k$  by  $\tilde{X}_{\mathcal{L}}$ , and the weights  $\lambda_1, \dots, \lambda_k$  by  $\Lambda_{\mathcal{L}}$ . Thus, (4.2) can be equivalently written as

$$\Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}}) := \sum_{i \in \mathcal{L}} \lambda_i \Delta^{\mathcal{J}}(x, \tilde{x}^i). \quad (4.3)$$

In the following, we are repeatedly going to use some variant of (4.3) as objective in the projection step of FP. Hence, in the projection step we have to solve the following LP

$$\begin{aligned} \min \quad & \sum_{i \in \mathcal{L}: \lambda_i > 0} \lambda_i \left( \sum_{j \in \mathcal{J}: \tilde{x}_j^i = l_j} (x_j - l_j) + \sum_{j \in \mathcal{J}: \tilde{x}_j^i = u_j} (u_j - x_j) + \sum_{j \in \mathcal{J}: l_j < \tilde{x}_j^i < u_j} d_j^i \right) \\ \text{s.t} \quad & x \in P_{\text{LP}} \\ & d_j^i \geq \tilde{x}_j^i - x_j, \quad i \in \mathcal{L}, j \in \mathcal{J} : \lambda_i > 0, l_j < \tilde{x}_j^i < u_j \\ & d_j^i \geq x_j - \tilde{x}_j^i, \quad i \in \mathcal{L}, j \in \mathcal{J} : \lambda_i > 0, l_j < \tilde{x}_j^i < u_j \\ & d_j^i \in \mathbb{R}, \quad i \in \mathcal{L}, j \in \mathcal{J} : \lambda_i > 0, l_j < \tilde{x}_j^i < u_j. \end{aligned} \quad (4.4)$$

In (4.4) each term of the objective function  $\Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}})$  is linearized separately, as explained in Chapter 1. Note that for each distance function  $\Delta^{\mathcal{J}}(x, \tilde{x}^i)$ ,  $i \in \mathcal{L}$ , with  $\lambda_i > 0$ , we create auxiliary variables  $d_j^i$  for every  $j \in \mathcal{J}$  with  $l_j < \tilde{x}_j^i < u_j$ , and add the constraints

$$\begin{aligned} d_j^i &\geq \tilde{x}_j^i - x_j \\ d_j^i &\geq x_j - \tilde{x}_j^i, \end{aligned}$$

in the projection step LP.

Moreover, a combination with the OFP objective is straightforward. In this case, the objective function of (4.4) is replaced by

$$\Delta_{\alpha}^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}}) := (1 - \alpha_k) \Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}}) + \frac{\alpha_k \|\Delta^{\mathcal{J}}\|_2}{\|c\|_2} c^{\top} x. \quad (4.5)$$

Here,  $\|\Delta^{\mathcal{J}}\|_2$  is the Euclidean norm of the objective function vector of (4.4). Note that for the special case where  $\lambda_k = 1$  and  $\lambda_i = 0$  for all  $i \in \mathcal{L} \setminus \{k\}$  the objective (4.5) is equal to (4.1).

### Weighted Sum of Integer Vectors

In the previous section we considered a weighted sum of distance functions in the projection step objective of FP. Another idea is to create a single aggregated reference vector  $\tilde{x}^{agg}$ , e.g., a convex combination of the vectors  $\tilde{x}^i$ ,  $i \in \mathcal{L}$  defined as

$$\tilde{x}^{agg} := \sum_{i \in \mathcal{L}} \lambda_i \tilde{x}^i, \quad \lambda_i \geq 0, \quad \sum_{i \in \mathcal{L}} \lambda_i = 1. \quad (4.6)$$

and replace  $\Delta^{\mathcal{J}}(x, \tilde{x}^k)$  in (4.1) by

$$\Delta^{\mathcal{J}}(x, \tilde{x}^{agg}) = \Delta^{\mathcal{J}}(x, \sum_{i \in \mathcal{L}} \lambda_i \tilde{x}^i). \quad (4.7)$$

Recall that the main goal of the projection step is to find a vector from  $P_{LP}$  close to some integer reference vector. However, the integer components of  $\tilde{x}^{agg}$  are not guaranteed to have an integer value, hence  $\tilde{x}^{agg}$  may not be a suitable choice. Ways to overcome this issue are presented later. Again, in case  $\lambda_k = 1$  and  $\lambda_i = 0$  for all  $i \in \mathcal{L} \setminus \{k\}$ , it obviously holds that  $\tilde{x}^{agg}$  is equal to  $\tilde{x}^k$ .

### A closer look at both approaches

To gain a better understanding, in the following example, we explicitly state and compare the projection step objective of FP when using (4.3) and (4.7).

**Example 4.1.** Consider a BIP with two binary variables  $x_1, x_2 \in \{0, 1\}$ , and assume that the first two integer vectors computed by FP are  $\tilde{x}^1 = (0, 0)$ , and  $\tilde{x}^2 = (1, 0)$ , and both were not feasible. At the second iteration, the usual distance function of the projection step of FP is given by

$$\Delta^{\mathcal{J}}(x, \tilde{x}^2) = -x_1 + x_2 + 1.$$

For  $\lambda_1, \lambda_2 \geq 0$  the weighted sum of distance functions (4.3) is given by

$$\begin{aligned} \Delta^{\mathcal{J}}(x, \tilde{x}^1, \tilde{x}^2, \lambda_1, \lambda_2) &= \lambda_1 \Delta^{\mathcal{J}}(x, \tilde{x}^1) + \lambda_2 \Delta^{\mathcal{J}}(x, \tilde{x}^2) \\ &= (\lambda_1 - \lambda_2)x_1 + (\lambda_1 + \lambda_2)x_2 + \lambda_2. \end{aligned}$$

On the other hand, the distance function at  $\tilde{x}^{agg} = \lambda_1 \tilde{x}^1 + \lambda_2 \tilde{x}^2 = (\lambda_2, 0)$  is not straightforward to state, since  $\tilde{x}_1^{agg}$  is not an integer for any  $\lambda_1, \lambda_2 \notin \{0, 1\}$ . Obviously, if  $\lambda_2 \in \{0, 1\}$ , then  $\Delta^{\mathcal{J}}(x, \tilde{x}^{agg})$  is the distance to a previously visited integer vector. Otherwise, it holds that  $\tilde{x}_1^{agg} \notin \{0, 1\}$ , hence an auxiliary variable  $d_1 \in \mathbb{R}$  is introduced with coefficient 1 in  $\Delta^{\mathcal{J}}(x, \tilde{x}^{agg})$  and the constraints

$$\begin{aligned} d_1 &\geq \lambda_2 - x_1 \\ d_1 &\geq x_1 - \lambda_2, \end{aligned}$$

are added to the projection LP. The distance function to  $\tilde{x}^{agg}$  is given by

$$\Delta^{\mathcal{J}}(x, \tilde{x}^{agg}) = d_1 + x_2.$$

From the previous example, it becomes clear that the weights  $\Lambda_{\mathcal{L}}$  have to be chosen carefully. For instance, when choosing  $\lambda_1 = \lambda_2 = 0.5$ , the variable  $x_1$  has coefficient 0 in (4.3), thus even solutions with high fractional values for  $x_1$  do not increase the objective value of the projection step. On the other hand, the objective value of (4.7) is smaller for vectors with high fractional values for  $x_1$  when using the same values for  $\lambda_1$  and  $\lambda_2$ , which is exactly the opposite of our goal.

**Corollary 4.2.** The distance functions (4.3) and (4.7) are not equivalent.

*Proof.* Follows directly from Example 4.1 for  $\lambda_1 = \lambda_2 = 0.5$ .  $\square$

Note that the  $L_1$ -distance to the current integer vector  $\tilde{x}^k$  is used in the projection step of all FP variants in the literature. Two main reasons for this choice are that it can easily be linearized and that the set of its minimizers over  $\mathbb{R}^n$  contains only integer vectors w.r.t. the index set of integer variables  $\mathcal{J}$ . In particular, the set of minimizers

$$\arg \min_{x \in \mathbb{R}^n} \Delta^{\mathcal{J}}(x, \tilde{x}^k) = \{x \in \mathbb{R}^n \mid x_i = \tilde{x}_i^k, \text{ for all } j \in \mathcal{J}\},$$



contains all vectors from  $\mathbb{R}^n$  whose integer components coincide with those of  $\tilde{x}^k$ . On the other hand, both (4.3) and (4.7) can easily be linearized, too, but as seen in Example 4.1, the sets of their minimizers over  $\mathbb{R}^n$  may contain non-integer vectors. More precisely, for (4.7) the previous example shows that the set of its minimizers does not contain any integer vectors, since  $\tilde{x}^{agg}$  does not satisfy the integrality constraints. To resolve this issue, we propose to round  $\tilde{x}^{agg}$  using the rounding procedure of FP.

On the other hand, we can show that the set of minimizers of (4.3) always contains an integer vector. Moreover, if the weights  $\Lambda_{\mathcal{L}}$  fulfill a specific property, we can show that the set of minimizers contains integer vectors only. For better readability, we consider in the remainder of this section only IPs, i.e., MIPs with  $\mathcal{I} = \{1, \dots, n\}$ . The extension of the following results to the case of general MIPs is straightforward.

**Theorem 4.3.** *Let  $\mathcal{L} = \{1, \dots, k\}$  be the set of indices of  $k \in \mathbb{N}$  integers vectors  $\tilde{x}^1, \dots, \tilde{x}^k \in \mathbb{Z}^n$ . Further, let  $\mathcal{J} = \mathcal{I}$ ,  $\lambda_i \geq 0$ , for all  $i \in \mathcal{L}$ , and  $\Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}})$  be defined as in (4.3). The set of minimizers of  $\Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}})$  over  $\mathbb{R}^n$  contains always an integer vector.*

*Proof.* If  $\lambda_i = 0$  for all  $i \in \mathcal{L}$ , the claim clearly holds. Assume there exists  $i \in \mathcal{L}$  with  $\lambda_i > 0$ . The distance function  $\Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}})$  can be rewritten as

$$\begin{aligned} \Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}}) &= \sum_{i \in \mathcal{L}} \lambda_i \Delta^{\mathcal{J}}(x, \tilde{x}^i) \\ &= \sum_{i \in \mathcal{L}} \lambda_i \|x - \tilde{x}^i\|_1 \\ &= \sum_{i \in \mathcal{L}} \lambda_i \sum_{j \in \mathcal{J}} |x_j - \tilde{x}_j^i| \\ &= \sum_{j \in \mathcal{J}} \underbrace{\sum_{i \in \mathcal{L}} \lambda_i |x_j - \tilde{x}_j^i|}_{=: f_j(x_j)}. \end{aligned}$$

Thus,  $\Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}})$  is the sum of  $|\mathcal{J}|$  terms  $f_j(x_j)$ , where each term depends only on the variable  $x_j$  where  $j \in \mathcal{J}$ . Hence, the set of minimizers  $S := \arg \min_{x \in \mathbb{R}^n} \Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}})$  is the Cartesian product over the  $|\mathcal{J}|$  sets

$$\arg \min_{x_j \in \mathbb{R}} f_j(x_j), \quad j \in \mathcal{J}.$$

Note that  $f_j(x_j) > f_j(\min_{i \in \mathcal{L}} \tilde{x}_j^i)$  for all  $x_j < \min_{i \in \mathcal{L}} \tilde{x}_j^i$ , and similarly  $f_j(x_j) > f_j(\max_{i \in \mathcal{L}} \tilde{x}_j^i)$  for all  $x_j > \max_{i \in \mathcal{L}} \tilde{x}_j^i$ . Therefore,  $f_j$  attains a minimum from  $[\min_{i \in \mathcal{L}} \tilde{x}_j^i, \max_{i \in \mathcal{L}} \tilde{x}_j^i]$ .

Now, let  $x^* \in \mathbb{R}^n$  be a non-integer minimizer of  $S$ . Then, there exists  $r \in \mathcal{J}$ , such that  $x_r^* \notin \mathbb{Z}$ . Since  $x_r^*$  is a minimizer of  $f_r$ , it holds that

$$f_r(x_r^*) \leq f_r(x_r) \text{ for all } x_r \in \mathbb{R}. \quad (*)$$

Consider the sets  $L_r, U_r \subseteq \mathcal{L}$  defined as

$$L_r := \{i \in \mathcal{L} : \tilde{x}_r^i \leq x_r^*, i \in \mathcal{J}\},$$

and

$$U_r := \{i \in \mathcal{L} : \tilde{x}_r^i \geq x_r^*, i \in \mathcal{J}\}.$$

Since  $x_r^* \notin \mathbb{Z}$ , it holds that  $L_r \dot{\cup} U_r = \mathcal{L}$ . Then,

$$\begin{aligned} f_r(x_r^*) &= \sum_{i \in \mathcal{L}} \lambda_i |x_r^* - \tilde{x}_r^i| \\ &= \sum_{i \in L_r} \lambda_i |x_r^* - \tilde{x}_r^i| + \sum_{i \in U_r} \lambda_i |x_r^* - \tilde{x}_r^i| \\ &= \sum_{i \in L_r} \lambda_i (x_r^* - \tilde{x}_r^i) + \sum_{i \in U_r} \lambda_i (\tilde{x}_r^i - x_r^*) \\ &= \underbrace{\left( \sum_{i \in L_r} \lambda_i - \sum_{i \in U_r} \lambda_i \right)}_{=: \Delta \Lambda_r} x_r^* + \underbrace{\sum_{i \in L_r} \lambda_i \tilde{x}_r^i - \sum_{i \in U_r} \lambda_i \tilde{x}_r^i}_{=: \tau_r} \end{aligned}$$

From the choice of  $L_r$  and  $U_r$  it follows that for all  $x_r \in [\lfloor x_r^* \rfloor, \lceil x_r^* \rceil]$

$$f_r(x_r) = \Delta \Lambda_r x_r + \tau_r.$$

We distinguish between the following cases:

- $\Delta \Lambda_r < 0$ : If  $x_r^* > 0$ , then for any  $x_r \in [\lfloor x_r^* \rfloor, x_r^*)$  it holds that  $f_r(x_r) < f_r(x_r^*)$ , which contradicts (\*). If  $x_r^* < 0$ , then for any  $x_r \in (x_r^*, \lceil x_r^* \rceil]$  it holds that  $f_r(x_r) < f_r(x_r^*)$ , which also contradicts (\*).
- $\Delta \Lambda_r > 0$ : Leads to a contradiction analogous to the first case.
- $\Delta \Lambda_r = 0$ : For all  $x_r \in [\lfloor x_r^* \rfloor, \lceil x_r^* \rceil]$ , it holds that  $f_r(x_r) = f_r(x_r^*)$ ,

which shows that  $\Delta \Lambda_r = 0$ , and each vector of  $[\lfloor x_r^* \rfloor, \lceil x_r^* \rceil]$  is a minimizer of  $f_r$ . Therefore, for any  $j \in \mathcal{J}$  there exists an integer minimizer of  $f_j$ , which shows the existence of an integer vector in  $S$ .  $\square$

**Remark 4.4.** *Since  $\Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}})$  is convex, it follows that the set of its minimizers  $S$  is also convex. Further, from Theorem 4.3 it follows that  $S$  is the Cartesian product of integers values and/or closed intervals with integer limit points.*

**Corollary 4.5.** *Let  $\mathcal{L} = \{1, \dots, k\}$  be the set of indices of  $k \in \mathbb{N}$  integers vectors  $\tilde{x}^1, \dots, \tilde{x}^k \in \mathbb{Z}^n$ . Further, let  $\mathcal{J} = \mathcal{I}$ ,  $\lambda_i \geq 0$ , for all  $i \in \mathcal{L}$ , and  $\Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}})$  be defined as in (4.3). If for any two disjoint sets  $L, U \subseteq \mathcal{L}$  with  $L \cup U = \mathcal{L}$  it holds that*

$$\sum_{i \in L} \lambda_i - \sum_{i \in U} \lambda_i \neq 0, \quad (4.8)$$

*then the set of minimizers of  $\Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}})$  over  $\mathbb{R}^n$  contains only integer vectors.*

*Proof.* It follows immediately from the proof of Theorem 4.3.  $\square$

Corollary 4.5 introduces a condition on the weights  $\Lambda_{\mathcal{L}}$ , which ensures the integrality of the minimizers of (4.3). However, this does not imply that any set of weights fulfilling this condition is a meaningful choice for the projection step of FP. For instance, if at any iteration  $k$  it holds that  $\lambda_1 = \lambda_2 = \dots = \lambda_{k-1} > \lambda_k$ , then (4.8) is obviously fulfilled. But as  $k$  gets larger, the distance (4.3) does not change much. Hence, the solutions of the projection step could converge to some LP-feasible vector, and consequently FP may stall. Therefore, it is meaningful to consider only a few reference integer vectors and to carefully choose the weights  $\Lambda_{\mathcal{L}}$  to avoid such behavior.

In the following, let us denote by  $\mathcal{L}_{\text{active}}$  the set of indices of integers vectors, whose distance function contributes with a positive coefficient in the objective of the projection step, i.e.,

$$\mathcal{L}_{\text{active}} = \{i \in \mathcal{L} \mid \lambda_i > 0\}. \quad (4.9)$$

For example, one can consider the last  $p \in \{1, \dots, k\}$  integers vectors as reference, i.e.,  $\mathcal{L}_{\text{active}} = \{k - (p - 1), \dots, k\}$ , and weights  $\lambda_i > \lambda_{i'}$  for all  $i, i' \in \mathcal{L}_{\text{active}}$  with  $i > i'$ . In this case only the  $L_1$ -distance function of the last  $p$  integers contributes in the projection step objective, where those of later obtained integer vectors have a greater contribution. We are going to present different choices for  $\mathcal{L}_{\text{active}}$  and the corresponding weights in Chapter 5 and extensive computational experiments in Chapter 6.

In the next example, we illustrate one run of FP incorporating (4.3) in the projection step objective.

**Example 4.6.** *Consider the BP*

$$\begin{aligned} \min \quad & x_1 \\ \text{s.t.} \quad & 2x_1 - 12x_2 + 15x_3 \leq 2 \\ & -16x_1 - 19x_2 - 5x_3 \leq -16 \\ & 31x_1 + 44x_2 - 55x_3 \leq 31 \\ & -x_1 + x_2 \leq 0 \\ & x_j \in \{0, 1\} \quad \forall j \in \{1, 2, 3\} \end{aligned}$$

In this example,  $\mathcal{L}_{active}$  is going to contain the indices of the last two integer vectors, i.e.,  $\mathcal{L}_{active} = \{k-1, k\}$ , and weights  $\lambda_i = \frac{1}{2^{k-i}}$  for  $i \in \mathcal{L}_{active}$ . Obviously, at any iteration  $k$ , it holds that

$$\lambda_k = 1 > \frac{1}{2} = \lambda_{k-1},$$

therefore the weights fulfill condition (4.8). Note that in order to obtain unique solutions in each projection step we use 0.55-rounding instead of nearest rounding here.

The set of feasible solutions of the LP relaxation of the BP is the blue polytope depicted in Figure 4.2. The optimal solution of the LP relaxation is the vector  $\bar{x}^0 = (\frac{2}{5}, \frac{2}{5}, \frac{2}{5})$ . In the first iteration,  $\bar{x}^0$  is rounded to the vector  $\tilde{x}^1 = (0, 0, 0)$ . The objective function of the projection step is

$$\begin{aligned} \Delta^{\mathcal{J}}(x, \tilde{x}^1, 1) &= \Delta^{\mathcal{J}}(x, \tilde{x}^1) \\ &= x_1 + x_2 + x_3 \end{aligned}$$

and the solution of the projection LP is  $\bar{x}^1 = (\frac{9}{20}, \frac{9}{20}, \frac{1}{20})$ . In the second pumping iteration,  $\bar{x}^1$  is rounded to the vector  $\tilde{x}^2 = (1, 1, 0)$ . Now, for  $\mathcal{L}_{active} = \{1, 2\}$ , with  $\lambda_1 = \frac{1}{2}$ ,  $\lambda_2 = 1$ , the objective function of the projection step is given by

$$\begin{aligned} \Delta^{\mathcal{J}}(x, \tilde{x}^1, \tilde{x}^2, \frac{1}{2}, 1) &= \frac{1}{2}\Delta^{\mathcal{J}}(x, \tilde{x}^1) + \Delta^{\mathcal{J}}(x, \tilde{x}^2) \\ &= \frac{1}{2}(x_1 + x_2 + x_3) + (1 - x_1) + (1 - x_2) + x_3 \\ &= -\frac{1}{2}x_1 - \frac{1}{2}x_2 + \frac{3}{2}x_3 + 2. \end{aligned}$$

The optimal solution of the projection LP is the integer vector  $\bar{x}^2 = (1, 0, 0)$ , thus a feasible solution is found. On the other hand, when using the original FP, the objective function of the projection step in the second pumping iteration is

$$\Delta^{\mathcal{J}}(x, \tilde{x}^2) = (1 - x_1) + (1 - x_2) + x_3,$$

and the optimal solution of the projection step LP is the vector  $(1, 1, \frac{4}{5})$ , which does not satisfy the integrality constraints.

### Modified Perturbation Mechanism

Considering information from previous iterations in the projection step may increase the probability of cycling, since the distance function in the objective may not change much during the pumping loop. Therefore, it is essential to provide different ways to escape cycles, since an increased number of random perturbations, and especially restarts, may drastically reduce the success rate of FP.

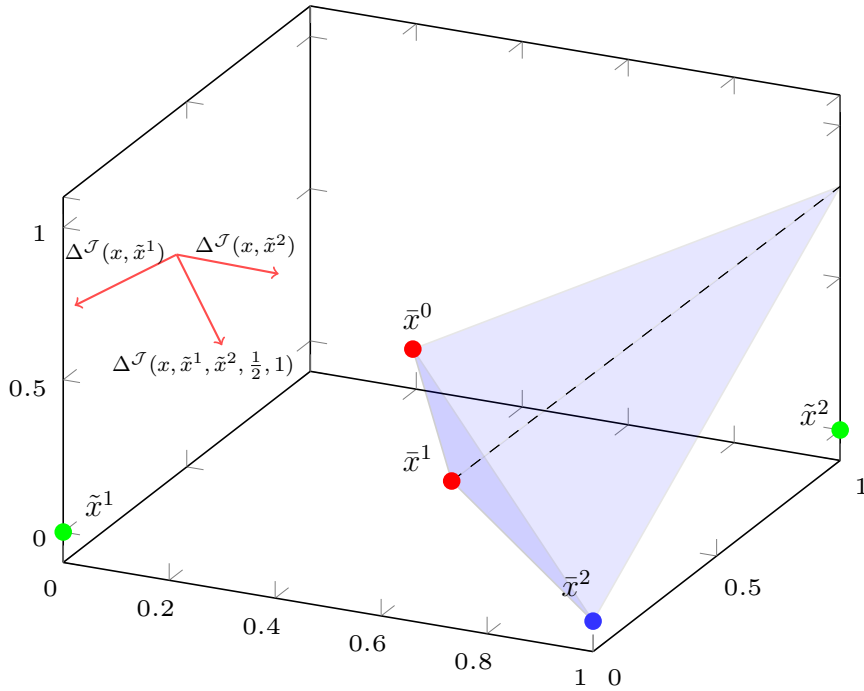


Figure 4.2.: BP with three variables that is solved after two pumping iterations when using (4.3) in the projection step.

Fortunately, in many cases, adjusting the weights  $\Lambda_{\mathcal{L}}$  may offer an alternative to random perturbations and restarts. For instance, if a cycle of length one is detected, i.e.,  $\tilde{x}^k = \tilde{x}^{k-1}$ , normally, a small number of integer components of  $\tilde{x}^k$  are set to a different integer value. One alternative way of hopefully breaking this cycle is to adjust the weights  $\Lambda_{\mathcal{L}}$  and repeat the iteration  $k - 1$ . Intuitively, since  $\tilde{x}^{k-1}$  is revisited, one could reduce the value of  $\lambda_{k-1}$ , i.e., reduce the contribution of  $\Delta^{\mathcal{J}}(x, \tilde{x}^{k-1})$  in (4.3). In case that a cycle of length greater than one is detected, i.e.,  $\tilde{x}^k = \tilde{x}^l$  for some  $l \in \{1, \dots, k-2\}$ , the restart mechanism can be avoided in a similar way. For instance, if  $l \in \mathcal{L}_{\text{active}}$ , we can set  $\lambda_l$  to a smaller value, or even to 0. More drastically, one can even use the original projection step of FP for one iteration by setting  $\lambda_k = 1$ , and  $\lambda_i = 0, i \in \mathcal{L} \setminus \{k\}$  to ignore all information from previous iterations. Lastly, if the cycle persists, or a new cycle is detected, the usual random perturbation or restart procedure can be used.

## 4.2. Alternative Objective Scaling

After experimenting with the problem instance `misc07`, Pradignac et al. [45] observed that for this instance the fixed scaling terms  $\|\Delta^{\mathcal{J}}\|_2$  and  $\|c\|_2$  do not provide a balanced contribution of  $\Delta^{\mathcal{J}}(x, \tilde{x}^k)$  and  $c^{\top}x$  in (4.1). Therefore, they proposed to replace  $\|c\|_2$  by  $|c^{\top}\bar{x}^{k-1}|$ , where  $\bar{x}^{k-1}$  is the LP-feasible vector obtained

in the projection step of the previous iteration. This modification resulted in a more balanced contribution of the two objective terms for this specific problem instance. However, no comparison over a large test set was presented.

Inspired by this idea, we propose to replace the scaling term  $\|\Delta^{\mathcal{J}}\|_2$  by the dynamically changing term  $|\Delta^{\mathcal{J}}(\bar{x}^{k-1}, \tilde{x}^k)|$ . In the spirit of this chapter, one can think of these two modification as considering information from previous iterations in the projection step. Remember that FP tries to close the distance of the vectors  $\bar{x}^k$  and  $\tilde{x}^k$ , and hopefully reach convergence. Thus, it is expected that the components of  $\bar{x}^k$  and  $\tilde{x}^k$  do not differ much from the corresponding components of  $\bar{x}^{k-1}$  and  $\tilde{x}^{k-1}$ . Consequently, in the projection step we also expect that  $\Delta^{\mathcal{J}}(x, \tilde{x}^k)$  and  $c^\top x$  will acquire values close to  $\Delta^{\mathcal{J}}(\bar{x}^{k-1}, \tilde{x}^k)$  and  $c^\top \bar{x}^{k-1}$ , respectively. Therefore, the new scaling terms could provide a more balanced contribution of the two objective terms. To summarize, we propose the modified projection step objective given by

$$\Delta_{\alpha_k}^{\mathcal{J}}(x, \tilde{x}^k) := (1 - \alpha_k)\Delta^{\mathcal{J}}(x, \tilde{x}^k) + \frac{\alpha_k |\Delta^{\mathcal{J}}(\bar{x}^{k-1}, \tilde{x}^k)|}{|c^\top \bar{x}^{k-1}|} c^\top x, \quad (4.10)$$

where  $\alpha_k \in [0, 1]$ . Note that a small value for  $|\Delta^{\mathcal{J}}(\bar{x}^{k-1}, \tilde{x}^k)|$  might also be an indicator of convergence in subsequent iterations. Whenever  $|\Delta^{\mathcal{J}}(\bar{x}^{k-1}, \tilde{x}^k)|$  decreases, the contribution of  $c^\top x$  in the objective also decreases, which turns the priority of the projection step more towards feasibility and less towards solution quality. Therefore, dynamically adjusting the two scaling terms may also accelerate the convergence to a feasible solution. Finally, a combination of (4.10) with the modifications of FP from the previous section is straightforward.

### 4.3. Multiple Reference Vectors in Stage 3

Recall that Stage 3 consists in solving the original MIP after replacing the original objective by the  $L_1$ -distance to an integer vector from the previous stage with minimal distance w.r.t.  $\mathcal{I}$  to  $P_{\text{LP}}$ . In the following, we propose two modifications of Stage 3. The first one is an extension of the idea from Section 4.1, and uses multiple integer reference vector in building the objective function of Stage 3. The second one uses a modified version of the *relaxation enforced neighborhood search* (RENS) heuristic of Berthold [6], which considers multiple LP-feasible reference vectors, to tighten the bounds of integer variables before solving the MIP.

#### Weighted Sum of Distance Functions

In a similar way to Section 4.1, instead of solving a MIP that minimizes the  $L_1$ -distance to a single integer vector, one could also consider a conic combination of

distance functions to the integers vectors  $\tilde{x}^i$ ,  $i \in \mathcal{L}$ ,

$$\Delta^{\mathcal{J}}(x, \tilde{X}_{\mathcal{L}}, \Lambda_{\mathcal{L}}) = \sum_{i \in \mathcal{L}} \lambda_i \Delta^{\mathcal{J}}(x, \tilde{x}^i), \quad (4.11)$$

where  $\lambda_i \geq 0$ , for all  $i \in \mathcal{L}$ . As before, the question that arises is which reference vectors and weights we shall choose. Again, we propose to consider a limited number of reference vectors. Intuitively, one could base the choice on their  $L_1$ -distances from  $P_{\text{LP}}$ , which is easily obtained after solving the projection step LP. Moreover, a natural choice of the corresponding weights in (4.11) is to set a larger weight the closer a reference vector is to  $P_{\text{LP}}$ . Further, variants of reference vectors and weights are discussed in Chapter 5.

### Multi-Reference RENS

The core idea of RENS is to search for feasible solutions of a MIP in the vicinity of the optimal solution of its LP relaxation  $\bar{x}^0$ . More specific, RENS solves a sub-MIP of the original MIP with tighter bounds for the integer variables based on their value in  $\bar{x}^0$ . To that end, for each  $j \in \mathcal{I}$ , if  $\bar{x}_j^0$  is an integer, then  $x_j$  is fixed at this value. Otherwise, the bounds of  $x_j$  are tightened to the two nearest integer values of  $\bar{x}_j^0$ , i.e.,  $l_j$  is set to  $\lfloor \bar{x}_j^0 \rfloor$ , and  $u_j$  to  $\lceil \bar{x}_j^0 \rceil$ . To summarize RENS solves the sub-MIP

$$\begin{aligned} \min_{x \in \mathbb{R}^n} \quad & c^\top x \\ \text{s.t.} \quad & Ax \leq b \\ & l_j \leq x_j \leq u_j \quad \text{for all } j \notin \mathcal{I}. \\ & \lfloor \bar{x}_j^0 \rfloor \leq x_j \leq \lceil \bar{x}_j^0 \rceil \quad \text{for all } j \in \mathcal{I}. \\ & x_j \in \mathbb{Z} \quad \text{for all } j \in \mathcal{I}. \end{aligned} \quad (4.12)$$

In practice, solving 4.12 may be computationally expensive if only a small percentage of integer variables is assigned tighter bounds. For example, applying RENS to a BIP, where most components of the LP-optimum are fractional, could be nearly as time-consuming as solving the original BIP. Therefore, Berthold [6] proposes to apply RENS within MIP solvers only if at least a specific ratio of all integer variables is fixed. On the other hand, if RENS tightens too many variable bounds, it may lead to infeasibility of (4.12). In the following, we propose to combine RENS with information obtained from Stage 1 and 2 of FP. During the pumping loop, FP generates a sequence  $\bar{x}^0, \dots, \bar{x}^k$  of LP-feasible vectors which can be used as reference vectors for RENS. Let  $\bar{X}$  be a subset of  $\{\bar{x}^0, \dots, \bar{x}^k\}$ . We propose a modified version of RENS, which we call *multi-reference RENS* (mRENS), in which the variable bound are tightened based on the values they take in vectors from  $\bar{X}$ . More precise for each  $j \in \mathcal{I}$ , we set  $l_j$  to  $\lfloor \min_{\bar{x} \in \bar{X}} \bar{x}_j \rfloor$ , and

$u_j$  to  $\lceil \max_{\bar{x} \in \bar{X}} \bar{x}_j \rceil$ . To summarize, mRENS solves the sub-MIP

$$\begin{aligned}
 & \min_{x \in \mathbb{R}^n} && c^\top x \\
 & \text{s.t.} && Ax \leq b \\
 & && l_j \leq x_j \leq u_j && \text{for all } j \notin \mathcal{I}. \\
 & && \lfloor \min_{\bar{x} \in \bar{X}} \bar{x}_j \rfloor \leq x_j \leq \lceil \max_{\bar{x} \in \bar{X}} \bar{x}_j \rceil && \text{for all } j \in \mathcal{I}. \\
 & && x_j \in \mathbb{Z} && \text{for all } j \in \mathcal{I}.
 \end{aligned} \tag{4.13}$$

Obviously, if the solution of the LP-relaxation  $\bar{x}^0$  of the original MIP is contained in the set of reference vectors  $\bar{X}$ , then infeasibility of problem (4.13) implies also infeasibility of (4.12). Note that both RENS and mRENS can be combined with the original objective of Stage 3 and also (4.11).



## Implementation and Computational Setup

In the first section of this chapter we discuss details regarding our implementation which is freely available and can be downloaded from <https://github.com/GioniMexi/feaspump3>. Afterwards, we present our computational setup, and the test set of MIP instances that we used. At last, we explain the goals of our computational study and the design of our experiments.

### 5.1. Implementation

As a baseline for our implementation we use the FP code that was kindly provided to us by Domenico Salvagnin [27]. The code is implemented in C++ and provides users the option to choose between FP, OFP, FP2.0, and OFP2. Moreover, it incorporates the WALKSAT perturbation procedure which we described in Section 3.3. In the implementation, FP communicates with LP/MIP solvers through an abstract class (interface), which is implemented for two state-of-the-art commercial solvers, namely, the FICO Xpress Optimizer [25] and IBM ILOG CPLEX [37].

#### New Options

In order to keep the implementation as flexible as possible, we introduced several additional parameter settings. In particular, when using OFP or OFP2, the boolean parameters *newScaleC* and *newScaleDelta* can be set to *true*, to replace in each pumping iteration  $k$  the scaling terms  $\|c\|_2$  by  $|c^T \bar{x}^{k-1}|$ , and  $\|\Delta^{\mathcal{J}}\|_2$  by  $|\Delta^{\mathcal{J}}(\bar{x}^{k-1}, \tilde{x}^k)|$ , respectively. The parameter *nIntsProj* sets the number of integer reference vectors in the projection step. The pumping loop maintains a list of all previously obtained integer vectors, with the current integer being always pushed in front of the list. By default the first  $p := nIntsProj$  elements of that list are chosen, which are  $\tilde{x}^k, \dots, \tilde{x}^{k-(p-1)}$ . Moreover, we enable further choices for the

reference vectors. By setting the boolean parameter *smallestViolInts* to *true*, the first reference vector is  $\tilde{x}^k$  and the remaining  $p - 1$  are previously obtained integers vectors  $\tilde{x}^l$ ,  $l \in \{1, \dots, k - 1\}$  with the smallest sum of violation over all constraints. For a MIP in the form (1.1), a vector  $\tilde{x} \in \mathbb{R}^n$  violates the constraints by  $\sum_{i=1}^m \max\{0, a_i^T \tilde{x} - b_i\}$ , where  $a_i \in \mathbb{R}^n$  contains the coefficients of the  $i$ -th row of the constraint matrix  $A$ . In a similar way, by setting *smallestDistInts* to *true*, the first reference vector is  $\tilde{x}^k$  and the rest  $p - 1$  are previously obtained integers vectors  $\tilde{x}^l$  with smallest  $L_1$ -distance  $\Delta^{\mathcal{J}}(\tilde{x}^l, \tilde{x}^k)$ . For both choices, the first reference vector is always the one obtained in the current pumping iteration and the remaining are sorted by their violation or distance, respectively. Let  $\tilde{x}^{ref,1}, \dots, \tilde{x}^{ref,p}$ , be the  $p$  reference vectors. Each of them is associated with a weight  $\lambda_i > 0$ ,  $i \in \{1, \dots, p\}$ . By setting the parameter *harmonicWeights* to *true*, the weights are obtained by the harmonic progression, i.e.,  $\lambda_i = \frac{1}{i}$ . Otherwise, if *harmonicWeights* is *false*, the parameter *decayFactorWeights* can be set to a value  $r \in (0, 1]$ , in order to obtain the weights  $\lambda_i = r^i$ . Note that if *decayFactorWeights* = 0.5 the weights are given by the geometric progression, and if *decayFactorWeights* = 1.0, then all weights are equal to 1. In all cases, the weights are scaled such that their sum is equal to 1. The last parameter regarding multiple reference vectors in the projection step is *aggregateInts*. If the parameter is set to *false*, then as explained in Section 4.1, we replace the term  $\Delta^{\mathcal{J}}(x, \tilde{x}^k)$  in the projection step objective by

$$\Delta^{\mathcal{J}}(x, \tilde{x}^{ref,1}, \dots, \tilde{x}^{ref,p}, \lambda_1, \dots, \lambda_p) = \sum_{i=1}^p \lambda_i \Delta^{\mathcal{J}}(x, \tilde{x}^{ref,i}).$$

Otherwise, if *aggregateInts* is *true*, then as explained in Section 4.1, we compute

$$\tilde{x}^{agg} := \sum_{i=1}^p \lambda_i \tilde{x}^{ref,i},$$

and since the integer components of  $\tilde{x}^{agg}$  are not guaranteed to take an integer value, we apply the rounding procedure of FP on this vector. Finally, we replace  $\Delta^{\mathcal{J}}(x, \tilde{x}^k)$  in the projection step objective by  $\Delta^{\mathcal{J}}(x, \tilde{x}^{agg})$ . Whenever FP detects a cycle with length greater than one, and  $p > 1$ , then instead of a restart, we set  $p = 1$ , i.e., use FP, for one iteration. If the same or a new cycle is detected, then we apply the restart procedure as usual.

Similar parameters are introduced for Stage 3. Here, the parameter *nIntsS3* sets the number of integer reference vectors. Assume FP enters Stage 3 after  $K$  iterations in Stage 1 or 2. By default we pick the  $s := nIntsS3$  integer vectors from the previous stage with smallest  $L_1$ -distance from the polyhedron  $P_{LP}$  associated with the LP-relaxation. By setting the parameter *smallestDistObjS3* to *true*, we choose  $s$  integer vectors  $\tilde{x}^i$ ,  $i \in \{1, \dots, K\}$  with smallest score

$$score(\tilde{x}^i) = \Delta^{\mathcal{J}}(\tilde{x}^i, \tilde{x}^i) \cdot (1 + |c^T \tilde{x}^i - c^T \tilde{x}^0|). \quad (5.1)$$

The score considers both the  $L_1$ -distance from  $P_{LP}$  and the absolute gap of  $c^\top \tilde{x}^i$  from the dual bound  $c^\top \tilde{x}^0$ . The weights of the reference vectors are adjusted based on the values of the parameters *harmonicWeightsS3* and *decayFactorWeightsS3*, which define weights in a similar way as *harmonicWeights* and *decayFactorWeights*, respectively. Let  $\tilde{x}^{refS3,1}, \dots, \tilde{x}^{refS3,s}$ , be the reference vectors. Then, Stage 3 solves the original MIP after replacing the objective  $c^\top x$  by

$$\Delta^{\mathcal{I}}(x, \tilde{x}^{refS3,1}, \dots, \tilde{x}^{refS3,p}, \lambda_1, \dots, \lambda_p) = \sum_{i=1}^p \lambda_i \Delta^{\mathcal{I}}(x, \tilde{x}^{ref,i}).$$

Finally, users can set *mRENS* to *true*, to tighten the integer variable domains based on all previously obtained LP-feasible vectors as explained in Section 4.3. In the future, we plan to refine this procedure by considering only a meaningful subset of LP-feasible vectors. Further, mRENS can be used also with the original objective of the MIP, by setting both parameters *mRENS* and *mRENSObj* to *true*.

### SoPlex/SCIP Interface

To test the robustness of FP with different LP/MIP solvers we decided to implement an additional interface for the noncommercial solver SCIP (Gamrath et al. [31]). SCIP uses external solvers to solve LP relaxations. One of those is the LP solver SoPlex (Wunderling [53]). The communication between SCIP and SoPlex is realized through an LP interface. In our implementation, we use SCIP to pre-solve the input MIP, and to get information about the variable types. Then, we extract the LP at the root node of the Branch-and-Bound algorithm and keep both the MIP and LP in memory. The LPs in the projection step of Stage 1 and 2 are solved by SoPlex, whereas the MIP in Stage 3 is solved by SCIP. To use SoPlex and SCIP as underlying solvers, users can simply set the parameter *solver* to “*scip*”. To the best of our knowledge, this is the first state-of-the-art OFP2 implementation that only uses open source software.

### FP Variants from the Literature

One of our side goals is to include further FP variants in the implementation. We extended the code with the Analytic Center FP (ACFP), and the Reweighted FP (RFP) with exponential weights. The details of these two FP variants can be found in [3] and [21], respectively. For ACFP users can set the parameter *acFP* to *true*, and for RFP the parameter *expRFP* to *true*. Note that incorporating additional FP variants can prove useful when using FP in multistart or parallel frameworks (see for example [36, 39]). However, such experiments are beyond the scope of this thesis.

## 5.2. Computational Setup and Test Set

In all computational experiments OFP2 is our baseline algorithm. From now on we abbreviate OFP2 by FP. The main focus of our experiments is to test new configurations of FP as standalone procedures. All results were obtained on a cluster of Intel Xeon E5-2690 @ 2.6 GHz machines with 128 GB of RAM, a time limit of 3600 seconds, and exclusive runs for each job.

### Names of different FP configurations

Based on the values of the new parameters, we name different configurations of FP in the following way. We extend the annotation FP by  $+(nints^{(agg)}, choice, weights, c, \Delta)+s3(nintsS3, choiceS3, weightsS3)$ , where:

- $nints = nIntsProj$ . If  $aggregateInts$  is *true*, then  $nints$  gets the superscript “agg”.
- $choice \in \{“l”, “sv”, “sd”\}$ , where  $choice$  is: “l” if the last obtained  $nints$  integer vectors are used as reference, “sv” if  $smallestViolInts = true$ , and “sd” if  $smallestDistInts = true$ .
- $weights \in \{“h”, “g”, “s”,  $decayFactorWeights$ \}$ , where  $weights$  is: “h” if  $harmonicWeights = true$ , and in case  $harmonicWeights = false$ , it is “g” if  $decayFactorWeights = 0.5$ , “s” if  $decayFactorWeights = 1.0$ , or otherwise it simply denotes the value  $decayFactorWeights$ .
- The letters “c”, and/or “ $\Delta$ ” are included in the configuration name if  $newScaleC = true$  and/or  $newScaleDelta = true$ , respectively.
- $nintsS3 = nIntsS3$ .
- $choiceS3 \in \{“sd”, “sdo”\}$ , where  $choiceS3$  is: “sd” if  $smallestDistObjS3$  is *false*, and “sdo” otherwise.
- $weightsS3 \in \{“h”, “g”, “s”,  $decayFactorWeightsS3$ \}$ , with values based on the parameters  $harmonicWeightsS3$  and  $decayFactorS3$ , in an analogous way as for  $weights$ .

Moreover, the configuration name is extended by “+mRENS( $\Delta$ )” if  $mRENS$  is *true* and by “+mRENS(c)”, if both  $mRENS$  or  $mRENSObj$  are *true*.

For example, if we consider in the projection step the last three integer vectors with harmonic weights, and  $aggregateInts$  is set to *false*, the configuration is called FP+(3,l,h). If we consider FP with both new scaling terms, the configuration is called FP+(c, $\Delta$ ). Moreover, a combination of both previous configurations is denoted by FP+(3,l,h,c, $\Delta$ ). Further, if in Stage 3 FP+(3,l,h,c, $\Delta$ ) considers three integer reference vectors with  $decayFactorWeightsS3 = 1.0$ , then the configuration is named FP+(3,l,h,c, $\Delta$ )+s3(3,sd,s).

## Settings

For our computations we use the parameter settings for FP as suggested in [1, 4]. In particular, the maximum number of iterations in Stage 1 and 2 are set to  $maxIterS1 = 10000$  and  $maxIterS2 = 2000$ , respectively. The maximum number of consecutive iterations without a 10% decrease of the distance between  $\tilde{x}^k$  and  $\bar{x}^k$  is set to  $maxIterNoImprS1 = 70$  for Stage 1, and to  $maxIterNoImprS2 = 600$  for Stage 2. The time limit for Stage 3 is set to  $\min\{timeS1S2, 3600 - timeS1S2\}$ , where  $timeS1S2$  is the total time spent in Stage 1 and 2. Since we use the OFP objective for the projection step, we set  $\alpha_1 = 0.9$ ,  $\phi = 0.9$ , and  $\delta_\alpha = 0.005$ . Lastly, the parameter  $avgPert$  is set to 20.

In our main computations we decided to use Xpress as LP solver in Stage 1 and 2 and as MIP solver in Stage 3. Before running FP, we apply the MIP presolving of Xpress. Each configuration is tested on the complete test set with three different seeds, since comparing configurations only with one seed may not provide a fair comparison, due to the random effects of perturbations and restarts. In most cases, the random seed may not be crucial for the success of the FP on a given instance, however it may still affect the solution quality and the number of iterations needed to terminate. Therefore, we decided to use average results over all three seeds to compare different FP configurations. For details about performance variability in mixed integer programming we refer to Lodi and Tramontani [41].

## Test set

Our computational experiments were performed on a large test set consisting of the official benchmark set MIPLIB 2017 [33] and all instances used in [27] that are not part of MIPLIB 2017. We excluded the instances `decomp2`, `ex9`, and `ex10`, since they were solved to optimality during presolve, and `supportcase19`, since solving its LP relaxation exceeded one hour of computation. In total our main test set consists of the 283 instances shown in Table A.1 in Appendix A. The columns from left to right contain the name of the problem, the total number of variables, binary variables, general integer variables, linear constraints, nonzeros in the constraint matrix, and the objective value of the optimal, or best known, solution.

## Comparing configurations over the test set

In the next chapter, we measure the performance of different FP configurations over our test set. Remember the definition of the geometric mean with shift.

**Definition 5.1.** Let  $n \in \mathbb{Z}_{\geq 0}$ ,  $V = \{v_1, \dots, v_n \mid v_i \in \mathbb{Z}_{\geq 0}\}$ , and  $s \in \mathbb{R}_{\geq 0}$ . The

geometric mean of  $V$  with shift  $s$  is defined as

$$h(V, s) := \sqrt[n]{\prod_{i=1}^n (v_i + s)} - s.$$

In the following we consider the geometric mean always with shift  $s = 1$ . Further, when mentioning restarts, we refer to the total number of perturbations and restarts. As already mentioned, all different FP configurations are tested over the whole test set with the same three random seeds. When solving an instance by some FP configuration the primal gap, running time, and number of iterations and restarts are given by the geometric mean over all runs that terminated with a feasible solution.

To provide a meaningful comparison of FP configurations, we will compare both their performance over single instances (number of wins) and over the whole test set (geometric means). All comparisons are done over instances for which all comparing configurations found a feasible solution with all three seeds. Over those instances, we count the number of wins, i.e., the number of instances a configuration provides at least a 10% relative improvement, for the primal gap, running time, number of iterations, and restarts. Note that wins w.r.t. the number of iterations, and restarts are counted only over instances that were solved solely in Stage 1 or 2. For the performance over the whole test set, we compare the geometric means for the primal gap, running time, number of iterations, and restarts. Again, the geometric mean w.r.t. the number of iterations and restarts is computed over instances that were solved solely in Stage 1 and 2.

### 5.3. Experimental Design

In this section we provide details regarding the logic behind our computational study. Our main goal is to answer the question of how different values for the new parameters affect the performance of FP, and to hopefully provide an improved version of FP. Our computational study is split in two parts. In the first part, we conduct experiments with configurations of FP which consider many different combinations of parameters regarding the projection step. Then, we extend our best performing configuration (FP3) with different combinations of parameters regarding Stage 3.

The goal of our first experiment is to analyze the impact of using multiple integer reference vectors in the projection step of FP. In doing so, we compare FP to configurations that consider the last obtained 2,3,5, or 10, integer vectors with two types of weights, namely, geometric or harmonic weights. Note that the parameter *aggregateInts* is always set to *false*, which means that we do not aggregate integer vectors, but consider a weighted combination of  $L_1$ -distance functions in the objective. Preliminary results indicate that configurations with

$aggregateInts = true$  worsen the performance of FP w.r.t. the solution quality and running time. Remember that  $\tilde{x}^{agg}$  may not be an integer vector. Thus, before the projection step, we apply the rounding procedure of FP once more on  $\tilde{x}^{agg}$ . The performance deterioration can be justified by two important observations. Firstly, before rounding,  $\tilde{x}^{agg}$  is in most cases not LP-feasible and therefore it is expected that the same holds for its rounding. Secondly, the rounding procedure does not consider the original objective of the MIP. Thus, multiple calls in each iteration can rapidly lead the search in regions with low quality solutions. Moreover, preliminary results indicate that considering multiple integer reference vectors with  $decayFactorWeights = 1.0$  leads to an increased frequency of cycling. This is an expected behavior, since in this case the  $L_1$ -distance functions of previously obtained integer vectors have a large contribution in the projection step objective.

Next, we analyze the impact of different choices of reference vectors. For that purpose, we pick some of the best performing configurations from our first experiment and run for each of them two additional tests. First, the reference vectors are chosen based on how much they violation the linear constraints of the MIP ( $smallestViolInts = true$ ), and second based on their  $L_1$ -distance to  $P_{LP}$  ( $smallestDistInts = true$ ).

In our third experiment we compare FP to configurations using the new scaling terms in the projection step objective. We observe that the new scaling terms and the use of multiple reference vectors provide complementary performance improvements. Therefore, we combine both ideas in our fourth experiment. Additionally, we test the robustness of our results by using CPLEX and SCIP as underlying solvers. Our best performing configuration will be denoted by FP3. Table 5.1 provides an overview of all previously explained experiments.

Table 5.1.: Tested configurations with a modified projection step.

experiments	configurations FP+(*)
# and weights of ref. vectors	(2,l,g), (3,l,g), (5,l,g), (10,l,g), (2,l,h), (3,l,h), (5,l,h), (10,l,h)
choice of ref. vectors	(3,sd,g), (3,sv,g), (3,sd,h), (3,sv,h)
new obj. scaling	(c), ( $\Delta$ ), (c, $\Delta$ )
combination	(3,l,g,c, $\Delta$ ), (3,sv,g,c, $\Delta$ ), (3,l,h,c, $\Delta$ ), (3,sv,h,c, $\Delta$ )
CPLEX and SCIP	(c, $\Delta$ ), (3,sv,g), (3,sv,g,c, $\Delta$ )

Next, we analyze the performance of FP3 with a modified Stage 3. We consider three reference vectors with harmonic, geometric, and same weights. Further, the choice of the three vectors is either based on their distance from  $P_{LP}$  or on the score (5.1) ( $smallestDistObjS3 = true$ ).

Furthermore, we compare FP3 to configurations that make use of mRENS in Stage 3, either with the original objective of the MIP, or the Stage 3 objective. Again, we conduct similar tests with CPLEX and SCIP as underlying solvers. Table 5.2 provides an overview of all experiments regarding Stage 3.

Table 5.2.: Tested configurations with a modified Stage 3.

experiments	configurations FP3 <sup>1</sup> +(*)
choice and weights of ref. vectors	s3(3,sd,g), s3(3,sd,h), s3(3,sd,s), s3(3,sdo,g), s3(3,sdo,h), s3(3,sdo,s)
mRENS	mRENS( <i>c</i> ), mRENS( $\Delta$ )
CPLEX and SCIP	s3(3,sd,s), s3(3,sdo,s), mRENS( <i>c</i> ), mRENS( $\Delta$ )

<sup>1</sup> FP3 denotes FP+(3,sv,g,c, $\Delta$ )

At last, to illustrate the effectiveness of our modified version of FP, we use it to find feasible solutions for challenging instances from the International Timetabling Competition 2021 (Van Bulck et al. [50]). In the next chapter we discuss the results of our computational study.



In this chapter we report the results of our computational study. Our main goal is to improve the overall performance of OFP2 by fine-tuning the new parameters in our implementation. For details about the computational setup and the design of our experiments we refer readers to Sections 5.2 and 5.3. For the complete results we refer to Appendix A, or to our online supplement <https://github.com/GioniMexi/online-supplement-feaspump3>. In the following, FP is used as an abbreviation for OFP2.

## 6.1. New Stage 1 and 2 Configurations

In the first part of our computational study we conduct experiments with configurations of FP that consider various combinations of parameters regarding Stage 1 and 2.

### Number and Weights of Reference Vectors

In our first experiment, we analyze the performance of configurations using multiple integer reference vectors in the projection step objective. We consider in each iteration the 2, 3, 5, or 10 last obtained integer vectors, with geometric or harmonic weights. In Table 6.1 we compare FP to FP+(2,l,g), FP+(3,l,g), FP+(5,l,g), FP+(10,l,g), and in Table 6.2 to FP+(2,l,h), FP+(3,l,h), FP+(5,l,h), FP+(10,l,h). Details about the names of different configurations can be looked up in Section 5.2. From left to right, the columns of each table contain the configuration name, the number of instances solved by each configuration with all three seeds, one or two seeds, and instances not solved with any seed, respectively. The next four columns show the number of wins and losses against FP w.r.t. the primal gap (gap(%)), running time (time(s)), number of iterations (iter), and restarts (rest). The last four columns show the geometric means for the gap(%), time(s), iter, and rest, for each configuration. In the second header line we denote

the number of instances that we used for the computation of the geometric means, as explained in Section 5.2.

The results show that all configurations are able to solve an almost identical number of instances. In both comparisons all configurations score consistently more wins against FP w.r.t. the gap, and most of them provide a gap decrease in terms of geometric means. On the other hand, increasing the number of reference vectors leads to an increase of the running time, iterations, and restarts. This is an expected behavior, since using information from previous iterations leads to smaller changes of the distance function in the projection step objective, which can be seen as taking smaller “steps” towards convergence.

Table 6.1.: Comparison of configurations considering multiple reference vectors with geometric weights.

configuration	solved (#seeds)			#wins/#losses vs FP				geom. mean			
	all	some	none	gap(%)	time(s)	iter	rest	(270 instances)		(223 instances)	
								gap(%)	time(s)	iter	rest
FP	272	5	6	-	-	-	-	45.4	5.3	15.1	1.0
FP+(2,l,g)	272	4	7	<b>83</b> /57	43/61	26/57	34/45	<b>45.0</b>	5.5	15.8	1.1
FP+(3,l,g)	272	6	5	<b>83</b> /57	45/70	25/72	23/57	<b>41.2</b>	5.7	16.1	1.2
FP+(5,l,g)	272	2	9	<b>80</b> /65	34/92	17/87	18/79	<b>43.1</b>	5.8	16.8	1.4
FP+(10,l,g)	<b>273</b>	3	7	<b>87</b> /60	31/103	16/92	23/73	<b>40.7</b>	6.0	16.9	1.4

Table 6.2.: Comparison of configurations considering multiple reference vectors with harmonic weights.

configuration	solved (#seeds)			#wins/#losses vs FP				geom. mean			
	all	some	none	gap(%)	time(s)	iter	rest	(267 instances)		(207 instances)	
								gap(%)	time(s)	iter	rest
FP	272	5	6	-	-	-	-	42.9	5.3	13.2	0.8
FP+(2,l,h)	272	4	7	<b>83</b> /57	41/61	26/58	34/46	<b>42.8</b>	5.5	13.9	0.8
FP+(3,l,h)	271	6	6	<b>81</b> /53	33/76	19/69	20/64	<b>40.8</b>	5.6	14.3	0.9
FP+(5,l,h)	272	3	8	<b>94</b> /62	30/103	17/101	26/78	<b>39.3</b>	6.2	15.6	1.2
FP+(10,l,h)	272	5	6	<b>77</b> /74	32/130	12/105	20/84	<b>42.4</b>	7.2	18.1	1.6

In Table 6.3 we state the stage within which various FP configurations terminate whenever they solve an instance with all three seeds. FP is able to find a feasible solution for more instances in the first two stages than all other configurations. Note that FP+(10,l,h) solved significantly less instances in Stage 1 and 2. Again, increasing the number of reference vectors from previous iterations and considering large weights for the corresponding distance functions leads to smaller changes of the projection step objective. Thus, the algorithm is more prone to

cycling and slower convergence. It becomes clear that a large number of integer vectors, e.g., 10, has to be accompanied with weights that do not undermine progress. For example, regardless of the number of reference vector, geometric weights guarantee that the  $L_1$ -distance to the current integer vector contributes at least 50% in the objective.

Table 6.3.: Termination stage for instances solved with all three seeds.

configuration	solved (all seeds)		
	stage 1&2	stage 1&2&3	stage 3
FP	237	14	21
FP+(2,1,g)	233	15	24
FP+(3,1,g)	230	15	27
FP+(5,1,g)	232	22	18
FP+(10,1,g)	228	22	23
FP+(2,1,h)	233	15	24
FP+(3,1,h)	231	18	22
FP+(5,1,h)	229	14	29
FP+(10,1,h)	209	25	38

The previous results support the motivating idea of this thesis, that taking smaller “steps” in each pumping iteration can yield better quality solution. In the remainder of this section, whenever we consider multiple reference vectors, we always choose three with either geometric or harmonic weights. Both FP+(3,1,g) and FP+(3,1,h) find in many cases better quality solutions than FP and decrease the geometric mean of the gap over our test set by 4.2% and 2.1%, respectively. Moreover, when compared to configurations with more than three reference vectors, they require less running time, iterations, and restarts.

### Choice of Reference Vectors

Next, we analyze the performance of configurations that choose the three reference vectors in a different way. Namely, based on the  $L_1$ -distance of integer vectors from  $P_{LP}$  (option “sd”), or the total violation over the linear constraints of the MIP (option “sv”). In Table 6.4 we compare FP to FP+(3,1,g), FP+(3,sd,g), and FP+(3,sv,g), and in Table 6.5 to FP+(3,1,h), FP+(3,sd,h), and FP+(3,sv,h). In the first table we observe that FP+(3,sd,g) and FP+(3,sv,g) also outperform FP in terms of solution quality, with an increase in terms of running time, iterations, and restarts. In the second table we observe similar behavior. Note that when compared to FP, both FP+(3,sv,g), and FP+(3,sv,h), score more wins and less losses than FP+(3,1,g), and FP+(3,1,h), respectively, and improve the geometric mean of the gap even further. However, the solution quality improvement is accompanied with an increase in terms of running time, iterations, and restarts.

This increase can be justified by the fact that some integer vectors may be considered in many iterations, which could result in cycling and undermine convergence. The same reasoning can be used to explain the results in Table 6.6. As expected configurations with the options "sd" and "sv" terminate less often solely in Stage 1 or 2.

Table 6.4.: Comparison of configurations with various choices for the three reference vectors and geometric weights.

configuration	solved (#seeds)			#wins/#losses vs FP				geom. mean			
	all	some	none	gap(%)	time(s)	iter	rest	(268 instances)		(222 instances)	
								gap(%)	time(s)	iter	rest
FP	272	5	6	-	-	-	-	45.3	5.2	14.6	1.0
FP+(3,l,g)	272	6	5	<b>83</b> /57	45/70	25/72	23/57	<b>41.0</b>	5.5	15.7	1.2
FP+(3,sd,g)	270	7	6	<b>89</b> /60	33/82	15/76	19/62	<b>42.7</b>	5.6	16.4	1.3
FP+(3,sv,g)	271	4	8	<b>88</b> /53	46/86	16/80	26/63	<b>39.4</b>	5.7	16.5	1.3

Table 6.5.: Comparison of configurations with various choices for the three reference vectors and harmonic weights.

configuration	solved (#seeds)			#wins/#losses vs FP				geom. mean			
	all	some	none	gap(%)	time(s)	iter	rest	(269 instances)		(222 instances)	
								gap(%)	time(s)	iter	rest
FP	272	5	6	-	-	-	-	45.8	5.2	14.9	1.0
FP+(3,l,h)	271	6	6	<b>81</b> /53	33/76	19/69	20/64	<b>43.4</b>	5.5	16.1	1.2
FP+(3,sd,h)	270	7	6	<b>83</b> /61	36/82	17/77	22/68	<b>40.7</b>	5.7	16.8	1.4
FP+(3,sv,h)	271	5	7	<b>89</b> /47	37/97	18/76	23/65	<b>37.8</b>	5.8	16.3	1.3

Table 6.6.: Termination stage for instances solved with all three seeds.

configuration	solved (all seeds)		
	stage 1&2	stage 1&2&3	stage 3
FP	237	14	21
FP+(3,l,g)	230	15	27
FP+(3,sd,g)	226	22	22
FP+(3,sv,g)	225	18	28
FP+(3,l,h)	231	18	22
FP+(3,sd,h)	228	18	24
FP+(3,sv,h)	228	18	25

To conclude, compared to FP, both FP+(3,sv,g) and FP+(3,sv,h) yield a large improvement of the solution quality, namely, they decrease the geometric mean of the gap over our test set by 5.9% and 8.0%, respectively. However, compared to FP+(3,l,g) and FP+(3,l,h), they require more time to find feasible solutions. Therefore, after analyzing the performance of FP with alternative scaling terms, we are going to consider again all four configurations FP+(3,l,g), FP+(3,l,h), FP+(3,sv,g), and FP+(3,sv,h) in the final parts of this section.

### Alternative Objective Scaling

Next, we compare FP with configurations that use the alternative scaling terms introduced in Section 4.2. Table 6.7 summarizes the results obtained by FP, FP+( $c$ ), FP+( $\Delta$ ), and FP+( $c,\Delta$ ).

Table 6.7.: Comparison of configurations with alternative scaling terms.

configuration	solved (#seeds)			#wins/#losses vs FP				geom. mean			
	all	some	none	gap(%)	time(s)	iter	rest	(269 instances)		(226 instances)	
								gap(%)	time(s)	iter	rest
FP	272	5	6	-	-	-	-	45.9	5.2	16.0	1.2
FP+( $c$ )	270	7	6	<b>82/75</b>	<b>87/57</b>	<b>83/46</b>	<b>62/39</b>	<b>43.9</b>	5.2	<b>14.0</b>	<b>0.9</b>
FP+( $\Delta$ )	271	6	6	65/79	<b>93/45</b>	<b>86/37</b>	<b>51/32</b>	46.9	<b>4.7</b>	<b>13.1</b>	<b>0.9</b>
FP+( $c,\Delta$ )	272	2	9	71/78	<b>90/55</b>	<b>94/40</b>	<b>61/29</b>	<b>44.6</b>	<b>4.9</b>	<b>11.3</b>	<b>0.7</b>

The results indicate that all four configurations solve almost an identical number of instances with all three seeds. The new scaling terms, lead to a decrease of the running time, iterations, and restarts. In particular, all three configurations FP+( $c$ ), FP+( $\Delta$ ), and FP+( $c,\Delta$ ) score more wins than FP in terms of iterations, running time, and restarts. Moreover, FP+( $c$ ) scores also more wins regarding the gap, and a 1.9% gap improvement for the geometric mean. Further, we observe that even though FP+( $c,\Delta$ ) scores less wins than FP, w.r.t. the primal gap, the geometric mean over the whole test set is improved. More specific, the gap is 1.3% lower, it is 0.3 seconds faster, requires almost 30% less iterations for problems solved in Stage 1 or 2, and almost 40% less restarts.

Lastly, Table 6.8 presents the stage that various configurations terminate whenever they solve an instance with all three seeds. In this case, FP is able to find a feasible solution for slightly more instances in the first two stages than all other configurations. Recall that the scaling terms are changing dynamically. Thus, for some instances the oscillation of the projection step objective may be too large, which could affect the ability to converge in Stage 1 and 2. Nevertheless, the dynamically adjusting nature of the new scaling terms is mostly beneficial for FP, since it decreases the cycling frequency and drives the search quickly towards a feasible solution.

Table 6.8.: Termination stage for instances solved with all three seeds.

configuration	solved (all seeds)		
	stage 1&2	stage 1&2&3	stage 3
FP	237	14	21
FP+( $c$ )	230	18	22
FP+(\mathDelta)	235	13	23
FP+( $c,\Delta$ )	234	11	27

As we have seen, the new scaling terms and the use of multiple reference vectors enhance the performance of FP in a complementary way. In particular, the new scaling terms mostly lead to an improvement in terms of running time, iterations, and restarts, whereas using multiple reference vector improves the solution quality. Based on this, it seems natural to compare FP to combinations of those configurations, as we do next.

### Final Configurations

In Table 6.9 we compare FP to FP+(3,1,g, $c,\Delta$ ), FP+(3,1,h, $c,\Delta$ ), FP+(3,sv,g, $c,\Delta$ ), and FP+(3,sv,h, $c,\Delta$ ). For a better interpretation of the results we include in this table also FP+( $c,\Delta$ ), FP+(3,1,g), FP+(3,1,h), FP+(3,sv,g), and FP+(3,sv,h). The results show that all four configurations that combine multiple reference vectors and the new scaling terms perform similarly, and all of them outperform FP in terms of solution quality and simultaneously converge faster to feasible solutions. Moreover, FP+(3,1,g, $c,\Delta$ ) and FP+(3,1,h, $c,\Delta$ ) are able to solve two more instances than FP with all three seeds. Finally, in Table 6.10 we see that FP is able to solve more instances solely in Stage 1 and 2. Reason for this behavior have been already explained previously.

The most important takeaway of the first part of our computational study is that using multiple integer reference vectors results in better quality solutions. Additionally, when combined with the new scaling terms, the running time, and the number of iterations and restarts decreases too, and the solution quality improvement is preserved to a large extent.

One of our best performing FP variants is FP+(3,sv,g, $c,\Delta$ ) which reduces the average gap from 45.7% to 41.2%, i.e., is 9.8% better than FP, and simultaneously requires 4.0% less running time, 24.5% less iterations, and 40.0% less restarts.

Table 6.9.: Comparison of configurations considering multiple reference vectors and alternative scaling terms.

configuration	solved (#seeds)			#wins/#losses vs FP				geom. mean			
	all	some	none	gap(%)	time(s)	iter	rest	(267 instances)		(212 instances)	
								gap(%)	time(s)	iter	rest
FP	272	5	6	-	-	-	-	45.7	5.0	14.3	1.0
FP+( $c,\Delta$ )	272	2	9	71/78	<b>90</b> /55	<b>94</b> /40	<b>61</b> /29	<b>44.5</b>	<b>4.7</b>	<b>9.8</b>	<b>0.6</b>
FP+(3,l,g)	272	6	5	<b>83</b> /57	45/70	25/72	23/57	<b>41.5</b>	5.3	15.3	1.1
FP+(3,l,h)	271	6	6	<b>81</b> /53	33/76	19/69	20/64	<b>43.4</b>	5.3	15.6	1.2
FP+(3,sv,g)	271	4	8	<b>88</b> /53	46/86	16/80	26/63	<b>39.9</b>	5.5	15.9	1.3
FP+(3,sv,h)	271	5	7	<b>89</b> /47	37/97	18/76	23/65	<b>37.7</b>	5.5	15.9	1.3
FP+(3,l,g,c, $\Delta$ )	<b>274</b>	3	6	<b>82</b> /76	<b>83</b> /73	<b>78</b> /56	<b>51</b> /43	<b>43.0</b>	<b>4.9</b>	<b>10.8</b>	<b>0.6</b>
FP+(3,l,h,c, $\Delta$ )	<b>274</b>	3	6	<b>84</b> /68	<b>85</b> /76	<b>77</b> /59	47/57	<b>42.7</b>	<b>4.9</b>	<b>10.8</b>	<b>0.6</b>
FP+(3,sv,g,c, $\Delta$ )	271	4	8	<b>89</b> /72	<b>97</b> /73	<b>79</b> /53	<b>53</b> /42	<b>41.2</b>	<b>4.8</b>	<b>10.8</b>	<b>0.6</b>
FP+(3,sv,h,c, $\Delta$ )	270	5	8	<b>85</b> /65	<b>103</b> /73	<b>74</b> /52	46/50	<b>43.6</b>	<b>4.8</b>	<b>11.0</b>	<b>0.7</b>

Table 6.10.: Termination stage for instances solved with all three seeds.

configuration	solved (all seeds)		
	stage 1&2	stage 1&2&3	stage 3
FP	237	14	21
FP+( $c,\Delta$ )	234	11	27
FP+(3,l,g)	230	15	27
FP+(3,l,h)	231	18	22
FP+(3,sv,g)	225	18	28
FP+(3,sv,h)	228	18	25
FP+(3,l,g,c, $\Delta$ )	232	19	23
FP+(3,l,h,c, $\Delta$ )	231	18	25
FP+(3,sv,g,c, $\Delta$ )	230	18	23
FP+(3,sv,h,c, $\Delta$ )	226	18	26

Recall that FP is not only used as a standalone procedure, but is also implemented in MIP solvers. Next, we are going to determine if incorporating our FP variants into a MIP solver has any impact.

### Suitability to be Embedded into MIP Solvers

When embedded in MIP solvers, primal heuristics are usually run only for a short amount of time. Therefore, for FP implementations in MIP solvers (see

SCIP [31]) the iteration limit of Stage 1 and 2 is much smaller than those in our previous experiments and the computationally demanding Stage 3 is deactivated or only used under certain circumstances, e.g., if the distance of the closest integer vector to the LP-polyhedron  $P_{LP}$  is below a certain threshold. In this section, we investigate the capability of FP,  $FP+(c,\Delta)$ ,  $FP+(3,sv,g)$  and  $FP+(3,sv,g,c,\Delta)$  in finding feasible solutions exclusively in Stage 1 or 2 applying an upper limit of 100 iterations. Note that in the Feasibility Pump 2.0 publication [27] the iteration limit was set to 20, in order to evaluate the performance of the algorithm in an embedded setting.

Figure 6.1 shows that both  $FP+(c,\Delta)$  and  $FP+(3,sv,g,c,\Delta)$  are able to find a feasible solution for about half our test set under 20 iterations. On the other hand, FP is able to find a feasible solution for 40% of the instances under 20 iterations, and  $FP+(3,sv,g)$  for slightly less.

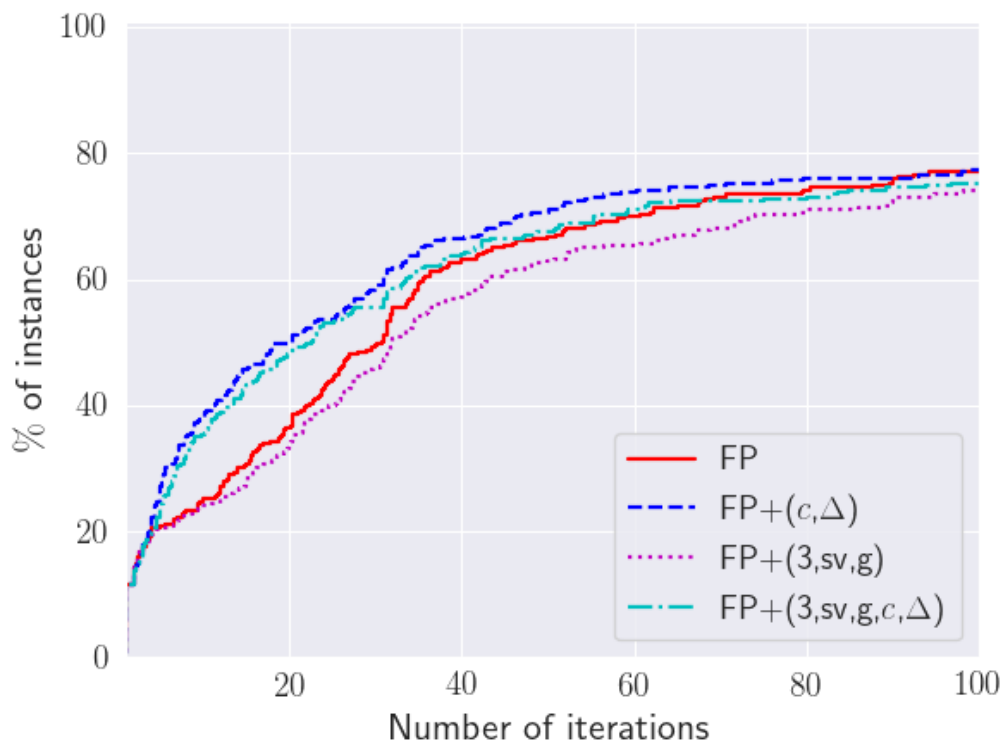


Figure 6.1.: Percentage of instances solved in Stage 1 or 2 under 100 iterations.

In Table 6.11 we present the exact number of solutions found in iterations ranges between 1 and 100. An astonishing result is that  $FP+(c,\Delta)$  and  $FP+(3,sv,g,c,\Delta)$  are able to find a feasible solution for 58.0% and 52.2% more instances than FP in less than 10 iterations. Furthermore, the success rate difference for under 20



iterations is still large. More precisely, in this range  $\text{FP}+(c,\Delta)$  finds solutions for 34.6% more instances than FP, and  $\text{FP}+(3,\text{sv},g,c,\Delta)$  for 28.0%.

Table 6.11.: Number of solution found under 100 iterations.

configuration	# solutions in iterations					
	1-10	1-20	1-30	1-40	1-50	1-100
FP	69	107	140	177	188	217
$\text{FP}+(c,\Delta)$	<b>109</b>	<b>144</b>	<b>165</b>	<b>187</b>	<b>199</b>	217
$\text{FP}+(3,\text{sv},g)$	66	98	128	161	176	207
$\text{FP}+(3,\text{sv},g,c,\Delta)$	<b>105</b>	<b>137</b>	<b>156</b>	<b>181</b>	<b>191</b>	211

Our results suggest that replacing FP by either  $\text{FP}+(c,\Delta)$  or  $\text{FP}+(3,\text{sv},g,c,\Delta)$  in MIP solvers could be beneficial, especially for solvers that use FP only for a few iterations. However, all previous results and our suggestion are based only on experiments with Xpress as underlying solver. Hence, the question that arises is whether our results generalize to other solvers.

### Performance with CPLEX and SCIP

In this section we investigate the performance of our FP variants with different LP/MIP solvers. In Table 6.12 we compare FP to  $\text{FP}+(c,\Delta)$ ,  $\text{FP}+(3,\text{sv},g)$ , and  $\text{FP}+(3,\text{sv},g,c,\Delta)$  with CPLEX as underlying solver, and in Table 6.13 with SCIP.

We observe that the overall behavior is similar to previous runs with Xpress. In particular, in both cases  $\text{FP}+(c,\Delta)$  always leads to a decrease of running time, iterations, and restarts. When using CPLEX,  $\text{FP}+(c,\Delta)$  finds feasible solutions for three more instances with all three seeds and in case of SCIP for four. On the other hand, similar to before,  $\text{FP}+(3,\text{sv},g)$  leads to solution quality improvement.

Finally, as seen in Table 6.12,  $\text{FP}+(3,\text{sv},g,c,\Delta)$  outperforms FP also with CPLEX. More specific, it is able to solve three more instances than FP with all three seeds, finds more often better quality solutions, and requires less iterations and restarts. However, unlike to the results with Xpress, it requires for 11 instances longer to terminate, but still, in terms of geometric means the running times are comparable. By using SCIP as underlying solver,  $\text{FP}+(3,\text{sv},g,c,\Delta)$  finds a feasible solution for one less instance with all three seeds, and leads to an improvement in terms of running time, iterations, and restarts. Even though it finds a better solution for one instance less, the geometric mean of the gap over the test set is decreased by 1.8%.

Table 6.12.: Performance with CPLEX.

configuration	solved (#seeds)			#wins/#losses vs FP				geom. mean			
	all	some	none	gap(%)	time(s)	iter	rest	(259 instances)		(210 instances)	
								gap(%)	time(s)	iter	rest
FP	264	9	10	-	-	-	-	42.8	6.2	15.5	1.2
FP+( $c,\Delta$ )	<b>267</b>	4	12	67/70	<b>74</b> /62	<b>98</b> /44	<b>67</b> /31	<b>41.2</b>	<b>5.8</b>	<b>10.7</b>	<b>0.6</b>
FP+(3,sv,g)	264	9	10	<b>89</b> /58	42/71	16/78	27/53	<b>39.8</b>	6.7	17.6	1.4
FP+(3,sv,g, $c,\Delta$ )	<b>267</b>	4	12	<b>85</b> /74	67/78	<b>79</b> /53	<b>53</b> /36	<b>41.1</b>	6.2	<b>11.9</b>	<b>0.7</b>

Table 6.13.: Performance with SCIP.

configuration	solved (#seeds)			#wins/#losses vs FP				geom. mean			
	all	some	none	gap(%)	time(s)	iter	rest	(236 instances)		(205 instances)	
								gap(%)	time(s)	iter	rest
FP	245	14	24	-	-	-	-	63.9	5.3	15.7	1.2
FP+( $c,\Delta$ )	<b>249</b>	9	25	53/71	<b>69</b> /44	<b>91</b> /39	<b>61</b> /21	66.5	<b>5.0</b>	<b>10.7</b>	<b>0.6</b>
FP+(3,sv,g)	<b>248</b>	12	23	<b>74</b> /45	39/57	24/69	33/52	<b>59.7</b>	5.3	16.8	1.3
FP+(3,sv,g, $c,\Delta$ )	244	17	22	67/68	<b>67</b> /54	<b>89</b> /39	<b>56</b> /32	<b>62.1</b>	<b>5.2</b>	<b>11.7</b>	<b>0.7</b>

There are many reason that justify the performance differences when using different LP/MIP solvers. Most importantly, solvers do not use the same presolving and LP/MIP solving techniques, which can alter the course of any FP algorithm. To summarize, regardless of the solver choice, FP+(3,sv,g, $c,\Delta$ ) consistently requires less iterations and restarts than FP, improves the solution quality, and has either improved or comparable running time. In the following, we denote FP+(3,sv,g, $c,\Delta$ ) by FP3 and we are going to analyze its performance with various combinations of parameter settings regarding Stage 3. Note that we use again Xpress as underlying solver.

## 6.2. New Stage 3 Configurations

As we have seen in the previous sections, using multiple integer reference vectors in the projection step objective is associated with an improvement of the solution quality. The question that arises is whether the same holds for configurations that use multiple integer reference vectors in Stage 3. In the second part of our computational study we conduct experiments with configurations of FP3 that consider various combinations of parameters regarding Stage 3. Note that in most cases FP3 terminates in Stage 1 or 2. Therefore, we decided to reduce the maximum number of iterations in each stage to 25 in order to force the execution of Stage 3. Our test set consists of all instances where FP3 did not find a feasible

solution after a total of 50 iterations. In particular, for Xpress as underlying solver we use the 62 instances shown in Table A.2. For CPLEX we use the 60 instances from Table A.3, and for SCIP the 65 instances from Table A.4. Additionally, the time limit for Stage 3 is set to  $3600 - \text{timeS1S2}$  seconds, where  $\text{timeS1S2}$  is the total time spent in Stage 1 and 2.

### Multiple Reference Vectors in the Objective

In Table 6.14 we compare FP3 to configurations that consider three integer reference vector with geometric, harmonic, or same weight. The reference vectors are chosen either by their distance to the polyhedron associated with the LP-relaxation  $P_{LP}$  (option "sd"), or by the score (5.1) (option "sdo"). The only two noticeable configurations are FP3+s3(3,sd,s) and FP3+s3(3,sdo,s). The first one, FP3+s3(3,sd,s), mostly improves the running time of Stage 3. In particular it decreases the running time by 11.5%. Moreover, it scores 4 more wins w.r.t. the gap, but in terms of geometric means the gap is slightly worse. The second one, FP3+s3(3,sdo,s), scores 9 more wins than FP3 w.r.t. the gap and provides a slight improvement for the geometric mean. However, in terms of running time it is slower than FP3.

Table 6.14.: Comparison of configurations using multiple integer reference vectors in Stage 3.

configuration	solved (#seeds)			#wins/#losses vs FP3		geom. mean	
	all	some	none	gap(%)	s3 time(s)	(59 instances)	
						gap(%)	s3 time(s)
FP3	62	0	0	-	-	85.8	2.6
FP3+s3(3,sd,g)	61	1	0	<b>14</b> /12	<b>15</b> /14	93.6	<b>2.5</b>
FP3+s3(3,sd,h)	61	1	0	8/14	<b>18</b> /14	96.9	<b>2.5</b>
FP3+s3(3,sd,s)	62	0	0	<b>13</b> /9	<b>23</b> /9	86.1	<b>2.3</b>
FP3+s3(3,sdo,g)	60	2	0	<b>18</b> /16	10/22	93.1	2.9
FP3+s3(3,sdo,h)	61	1	0	<b>17</b> /16	8/26	91.7	3.0
FP3+s3(3,sdo,s)	61	1	0	<b>24</b> /15	14/21	<b>83.3</b>	2.8

Unfortunately, our results are inconclusive. However, since our implementation allows us to use multiple MIP solvers, we are going to reconsider later both FP3+s3(3,sd,s) and FP3+s3(3,sdo,s) in experiments with CPLEX and SCIP and hopefully obtain some more knowledge about the effects of multiple integer vectors in Stage 3.

### Incorporating mRENS

Next, we compare FP3 to configurations that use mRENS in Stage 3. In our implementation mRENS can be used either with the original objective of the

MIP (mRENS( $c$ )), or with the Stage 3 objective (mRENS( $\Delta$ )). Again, there is no guarantee that the sub-MIP defined by mRENS is going to be feasible. In our experiments we want to simulate the following process. If mRENS finds a feasible solution, we terminate. Otherwise, we use the original Stage 3 for the remaining available time.

In Table 6.15 we compare FP3 to FP3+mRENS( $c$ ) and FP3+mRENS( $\Delta$ ). Both mRENS( $c$ ) and mRENS( $\Delta$ ) find a feasible solution for 25 out of 62 instances with all three different random seeds, and for 12 with one or two seeds. For the remaining 25 instances the sub-MIP is infeasible. Even though in almost half cases it is required to solve two MIPs, FP3+mRENS( $c$ ) and FP3+mRENS( $\Delta$ ) lead to a 10.0% and 23.3% improvement of the Stage 3 running time, respectively. At the same time, FP3+mRENS( $c$ ) finds in 35 cases better quality feasible solutions than FP3, and leads to a 49.8% decrease in terms of the geometric mean. Moreover, FP3+mRENS( $\Delta$ ) scores 8 more wins than FP3 w.r.t. the gap, and in terms of geometric means it provides a 10.9% decrease. In the parenthesis of the final columns of Table 6.15 we include the geometric means for the running time of mRENS( $c$ ) and mRENS( $\Delta$ ) over our test set, which shows that both methods terminate much faster than the original Stage 3, however without any guarantee of feasibility.

Table 6.15.: Comparison of configurations that use mRENS.

configuration	solved (#seeds)			#wins/#losses vs FP3		geom. mean	
	all	some	none	gap(%)	s3 time(s)	(62 instances)	
						gap(%)	s3 time(s)
FP3	62	0	0	-	-	87.4	3.0
FP3+mRENS( $c$ )	62(25)	0(12)	0(25)	<b>35</b> /0	<b>18</b> /13	<b>37.6</b>	<b>2.7</b> (0.9)
FP3+mRENS( $\Delta$ )	62(25)	0(12)	0(25)	<b>14</b> /6	<b>24</b> /6	<b>76.5</b>	<b>2.3</b> (0.6)

As already mentioned, many implementations of FP in MIP solvers skip the computationally demanding Stage 3. We strongly believe that mRENS( $c$ ) and mRENS( $\Delta$ ) are good alternatives for Stage 3 in embedded implementations of FP, since they require way less computational time. However, similar to the RENS heuristic, there is no guarantee that the defined sub-MIP is going to be feasible. From our analytic results in Table A.36 it can be induced that in most cases of infeasible sub-MIPs, Xpress is able to detect that in a short amount of time.

## RENS vs mRENS

Since mRENS tightens the domain of less integer variables than RENS, it is expected that the sub-MIP it solves is more often feasible. In Table 6.16 we present the geometric means of the percentages of fixed binaries and general

integers with tighter bounds when using RENS and mRENS. From this table it can be observed that even though mRENS considers 50 reference vectors it still tightens the bounds of a large amount of variables. This is an expected behavior, since by the design of FP most components of the LP-feasible vectors obtained during the pumping loop do not differ that much. In our case, we used FP3 which takes even smaller steps in each iteration. Therefore, it is expected that the LP-feasible vectors used by mRENS are like to be even closer to each other.

Additionally, applying mRENS after 50 iterations of FP3 finds feasible solutions for 29 instances where the sub-MIP defined by RENS is infeasible. Table 6.17 shows for each of the 29 instances the percentages of fixed binary variables and general integer variables with tighter bounds in the sub-MIP defined by RENS and mRENS, respectively. Further, for mRENS we include also the number of solutions found over the three runs with different seeds. For many instances mRENS tightens slightly less variable domains than RENS and by doing so, the defined sub-MIP becomes feasible. For example, for `swath1` RENS fixes 99.4% binary variables which results to an infeasible sub-MIP. On the other hand, mRENS fixes slightly less variables (98.1%) and the sub-MIP is in all three runs feasible. We conclude that using multiple LP-feasible reference vectors could probably be well combined with RENS. However, this is beyond the scope of this thesis.

Table 6.16.: Geometric means: (%) of tightened variables over the 62 instances.

	fixed bin.(%)	tightened int.(%)
RENS	71.2	43.3
mRENS	57.5	16.5

Table 6.17.: Instances where mRENS found feasible solutions and the sub-MIP solved by RENS was infeasible.

problem	RENS		# sols	mRENS	
	fixed bin.(%)	tightened int.(%)		fixed bin.(%)	tightened int.(%)
arki001	86.4	77.4	2	74.4	42.9
csched008	93.6	-	3	89.1	-
germanrr	97.8	98.1	2	94.5	94.8
ic97p	48.1	23.3	3	28.7	1.4
icir97p	42.7	9.6	3	23.4	2.8
neos-1456979	97.6	95.4	2	92.6	11.2
neos-1582420	88.9	62.0	3	85.7	59.3
neos-2746589-doon	98.7	58.9	1	97.7	28.9
neos-3216931-puriri	75.4	-	3	39.0	-
neos-3381206-awhea	50.1	89.8	3	18.2	36.6
neos-4338804-snowy	71.9	76.2	3	56.6	7.0
neos-4532248-waihi	98.5	-	3	83.5	-
neos-4722843-widden	95.3	31.8	3	94.3	25.1
neos-5104907-jarama	84.7	-	2	72.1	-
neos-5107597-kakapo	47.0	-	3	37.0	-
neos-960392	98.5	-	2	98.3	-
nh97p	48.4	8.4	1	30.4	2.3
ns1830653	65.9	-	3	14.4	-
physiciansched3-3	75.9	-	2	67.3	-
physiciansched6-2	78.8	-	2	67.5	-
rB12-111111	93.1	-	3	87.7	-
radiationm18-12-05	74.4	80.4	3	63.8	41.0
radiationm40-10-02	79.0	90.5	2	68.9	50.5
satellites2-60-fs	93.8	-	3	69.0	-
supportcase33	20.5	14.9	2	20.0	9.2
swath1	99.4	-	3	98.1	-
timtab1	62.3	10.8	3	52.2	2.8
timtab2	29.7	9.9	3	21.9	1.4
unitcal-7	70.2	-	1	67.3	-

## Performance with CPLEX and SCIP

Next, we analyze the performance of configurations with a modified Stage 3 with CPLEX and SCIP as underlying solvers. In Table 6.18 we compare FP3 to FP3+s3(3,sd,s), FP3+s3(3,sdo,s), FP3+mRENS( $c$ ), and FP3+mRENS( $\Delta$ ) with CPLEX, and in Table 6.19 with SCIP. In both experiments FP3+s3(3,d,s) and FP3+s3(3,do,s) do not lead to any improvements. Since our extensive tests with three solvers led to unsatisfactory results, we can conclude that the proposed way of using multiple integer reference vectors in Stage 3 does not benefit FP. This result emphasizes on the importance of validating results with multiple solvers. For example, using only one solver in this experiment could lead to wrong conclusion regarding the effects of multiple integer reference vectors in Stage 3.

On the other hand, FP3+mRENS( $c$ ), and FP3+mRENS( $\Delta$ ) lead to better quality solutions with CPLEX and SCIP too. However, FP3+mRENS( $c$ ) requires longer running time in Stage 3 than FP3, since for more than half instances we solve two MIPs instead of one. Nevertheless, with SCIP as underlying solver FP3+mRENS( $\Delta$ ) improves both the solution quality and running time simulta-

neously. In the parenthesis of the final columns of both tables we include the geometric means for the running time of mRENS( $c$ ) and mRENS( $\Delta$ ). Similar to Xpress, both methods terminate much faster than the original Stage 3, however without any guarantee of feasibility.

Table 6.18.: Performance of Stage 3 configurations with CPLEX.

configuration	solved (#seeds)			#wins/#losses vs FP3		geom. mean	
	all	some	none	gap(%)	s3 time(s)	(60 instances)	
						gap(%)	s3 time(s)
FP3	60	0	0	-	-	93.6	2.2
FP3+s3(3,sd,s)	60	0	0	7/10	13/14	103.0	2.3
FP3+s3(3,sdo,s)	60	0	0	<b>13</b> /10	10/18	102.0	2.4
FP3+mRENS( $c$ )	60(18)	0(10)	0(32)	<b>21</b> /3	5/31	<b>82.8</b>	3.5(1.6)
FP3+mRENS( $\Delta$ )	60(18)	0(10)	0(32)	<b>12</b> /8	7/30	<b>92.8</b>	3.4(1.2)

Table 6.19.: Performance of Stage 3 configurations with SCIP.

configuration	solved (#seeds)			#wins/#losses vs FP3		geom. mean	
	all	some	none	gap(%)	s3 time(s)	(63 instances)	
						gap(%)	s3 time(s)
FP3	63	2	0	-	-	164.3	6.8
FP3+s3(3,sd,s)	<b>64</b>	1	0	<b>10</b> /6	14/20	169.4	7.2
FP3+s3(3,sdo,s)	<b>64</b>	1	0	<b>13</b> /11	13/28	172.2	7.6
FP3+mRENS( $c$ )	63(24)	2(7)	0(34)	<b>26</b> /1	14/15	<b>98.7</b>	8.5(1.5)
FP3+mRENS( $\Delta$ )	63(24)	2(7)	0(34)	<b>13</b> /2	<b>20</b> /13	<b>135.2</b>	<b>6.5</b> (1.0)

The most important conclusion of the second part of our computational study is that both mRENS( $c$ ) and mRENS( $\Delta$ ) could provide a good alternative for Stage 3 in embedded implementations of FP. Even though the defined sub-MIP may not always be feasible, they both require way less computational time, which is an important feature for heuristics that are actually used inside MIP solvers.

### 6.3. Application: International Timetabling Competition 2021

In this section, we present our results after using FP+(3,l,g,c, $\Delta$ ) with Xpress as underlying solver to find feasible solutions for 45 challenging problems that are taken from the International Timetabling Competition 2021 (ITC 2021) [50]. Details about the ITC 2021 test set can be found in Table A.5. Note that for most instances it is very hard to find any feasible solution with MIP solvers. On

the other hand, once an initial solution is known, it can be often improved to a satisfactory level. Therefore, employing primal heuristics could be remarkably beneficial for such challenging problems. Our choice to use  $\text{FP}+(3,1,g,c,\Delta)$  is based on the fact that it is one of our best performing FP configurations and together with  $\text{FP}+(3,1,h,c,\Delta)$  it is able to find more feasible solutions than any other configuration over our main test set (see Table 6.9).

In our experiments we consider three variants of the ITC 2021 test set with different objective functions. The first one uses the original objective of the problems. In the second one the objective is removed, i.e., we consider a feasibility version of each problem. In the third variant the objective points towards the analytic center of the LP-polyhedron, with the hope to drive the search towards regions that contain feasible solutions. For details about the benefits of using information from interior points, e.g., the analytic center, in MIP algorithms we refer to Berthold et al. [8].

In Table 6.20 we present for each variant of the ITC 2021 test set the objective value of the best found solutions (best sol.) by  $\text{FP}+(3,1,g,c,\Delta)$  and the geometric mean of the running time (time(s)) after three runs with different random seeds. Note that the superscripts in the column “best sol.” denote the number of successful runs in case it is different from three.

For MIP formulations using the original objective, we are able to find a feasible solution for 20 out of 45 instances, always in Stage 1 or 2 and under one hour of computation. Next, for MIP formulations with no objective we are able to find solutions for 29 instances. Again all solutions are found solely in Stage 1 or 2 and under one hour of computation. In the final test we try to find solutions for the 16 unsolved instances by solving the MIP formulations where the objective points towards the analytic center of the LP-polyhedron. Here,  $\text{FP}+(3,1,g,c,\Delta)$  finds feasible solutions for the instances Early 4, Early 11, Middle 10, and Late 2, with objective values 1902, 10218, 2450, and 6305, respectively, within 10 minutes. Note that for those four instances a massive number of parallel runs of MIP solvers on 12288 CPU-cores of a supercomputer with a time limit of 12 hours could not generate any feasible solution.

To summarize, our results demonstrates the effectiveness of our modified version of FP as a standalone procedure. We were able to find feasible solutions for 33 out of the 45 ITC 2021 problems. All solutions were found in less than an hour and solely in Stage 1 or 2. Moreover, our last experiment, where the MIP objective uses coefficients that correspond to the analytic center, enables  $\text{FP}+(3,1,g,c,\Delta)$  to find solutions for four of the most challenging instances. This results delivers the new interesting idea of making use of the analytic center in the projection step of FP when tackling hard MIPs.



Table 6.20.: Feasible solution found by  $FP+(3,l,g,c,\Delta)$  for ITC 2021 instances.

problem	Original Obj.		Removed Obj.		AC Obj.	
	best sol.	time(s)	best sol.	time(s)	best sol.	time(s)
Early 1	-	-	31345.0 <sup>(1)</sup>	727.6		
Early 2	-	-	13877.0 <sup>(1)</sup>	1773.0		
Early 3	11553.0	724.0	19847.0	44.5		
Early 4	-	-	-	-	1902.0 <sup>(1)</sup>	336.6
Early 5	-	-	-	-	-	-
Early 6	-	-	-	-	-	-
Early 7	-	-	81137.0 <sup>(1)</sup>	3597.5		
Early 8	12038.0	561.5	31757.0	22.3		
Early 9	14518.0	1847.5	39128.0	26.4		
Early 10	-	-	-	-	-	-
Early 11	-	-	-	-	10218.0 <sup>(2)</sup>	282.2
Early 12	-	-	-	-	-	-
Early 13	1234.0	2888.2	1393.0	858.2		
Early 14	21221.0	1650.0	54734.0	53.4		
Early 15	-	-	46813.0 <sup>(1)</sup>	1662.5		
Middle 1	-	-	-	-	-	-
Middle 2	-	-	-	-	-	-
Middle 3	-	-	-	-	-	-
Middle 4	419.0	426.9	787.0	81.4		
Middle 5	15268.0	1489.5	32157.0	91.0		
Middle 6	-	-	49861.0 <sup>(1)</sup>	2563.2		
Middle 7	53809.0	1231.9	34333.0	551.8		
Middle 8	1096.0	1269.2	1408.0	154.3		
Middle 9	26050.0	2169.0	31030.0	83.0		
Middle 10	-	-	-	-	2450.0 <sup>(1)</sup>	596.4
Middle 11	-	-	-	-	-	-
Middle 12	-	-	53818.0 <sup>(2)</sup>	1242.8		
Middle 13	32599.0 <sup>(1)</sup>	3546.3	46854.0 <sup>(2)</sup>	1672.6		
Middle 14	-	-	30797.0	1002.6		
Middle 15	-	-	24764.0	180.7		
Late 1	19576.0	2108.5	19545.0	1009.3		
Late 2	-	-	-	-	6305.0 <sup>(1)</sup>	324.5
Late 3	35505.0	962.2	51758.0	366.5		
Late 4	1.0	487.6	2925.0	96.1		
Late 5	-	-	-	-	-	-
Late 6	37257.0	1647.7	14827.0	221.8		
Late 7	74661.0 <sup>(1)</sup>	3094.1	55603.0	1472.1		
Late 8	22063.0	1079.3	13448.0	75.0		
Late 9	5823.0	2194.1	31724.0	294.4		
Late 10	-	-	-	-	-	-
Late 11	-	-	-	-	-	-
Late 12	-	-	-	-	-	-
Late 13	-	-	106389.0 <sup>(1)</sup>	2123.8		
Late 14	3030.0 <sup>(2)</sup>	2798.5	39243.0	1357.1		
Late 15	2680.0	2205.2	54695.0	32.8		





## Conclusion and Future Work

This thesis was all about the Feasibility Pump as a standalone procedure. Besides explaining the main components of the algorithm, we presented an extensive overview of related literature, and most importantly the Objective Feasibility Pump 2.0 (OFP2), which was the baseline algorithm for our implementation.

We presented various extensions of the projection step, which do not only consider a single integer reference vector, but also integer vectors that are obtained in previous pumping iterations. This is achieved by using a conic combination of distance functions in the projection step objective. We were able to show that the minimizers of this conic combination are integer vectors if the weights in it fulfill a specific property. Moreover, we introduced alternative objective scaling terms to balance the contributions of the distance functions and the original MIP objective  $c^\top x$ .

Next, we extended the idea of using multiple reference vector to Stage 3 in two ways. First, in a similar way as before, we considered a conic combination of distance functions to multiple integer reference vectors directly in the objective. Second, we introduced a modified version of the RENS heuristic, which we called mRENS, that uses multiple LP-feasible vectors obtained during the pumping loop, to tighten the bounds of integer variables in Stage 3.

All previous ideas were incorporated in an OFP2 implementation. In addition, we provided a solver interface for the non-commercial solver SCIP, and also included two further FP variants from the literature in our implementation. To the best of our knowledge, this is the first state-of-the-art OFP2 implementation that only uses open source software. Our final version of the code is freely available and can be downloaded from <https://github.com/GioniMexi/feaspump3>.

Computational experiments over a large test set of MIP instances showed that our modifications in the projection step boost the performance of OFP2. More precisely, one of our best performing OFP2 variants was  $\text{FP}+(3,sv,g,c,\Delta)$ , which uses three reference vectors and the new objective scaling terms. This variant provided a 9.8% solution quality improvement, 4.0% decreased running time, and

24.5% less iterations. Especially the success rate within the first few iterations increased considerably. For example, it could find solutions for 52.2% more instances within ten iterations. Next to Xpress, we verified the consistency of our results also with CPLEX and SCIP as underlying solvers. Additionally, the results of the second part of our computational study indicated that mRENS could be a good alternative for Stage 3 in embedded implementations of FP. Even though the defined sub-MIP may not always be feasible, mRENS required way less computational time, which is an important feature for heuristics that are actually employed inside MIP solvers.

Finally, we used one of our improved versions of OFP2 to solve challenging instances from the International Timetabling Competition 2021. Our solutions contributed to the qualification of team MODAL from Zuse Institute Berlin to the competition finals. In particular, we were able to find feasible solutions for 33 out of 45 instances within minutes, and more importantly, for four instances where a massive number of parallel runs of commercial MIP solvers on 12288 CPU cores of a supercomputer could not find any feasible solutions in tens of thousands of CPU hours. Afterwards, MIP solvers were able to improve our initial solutions even further. This indicates that our version of OFP2 can remarkably benefit the performance of MIP solvers on problem classes where getting an initial feasible solution is very challenging.

In the near future, we seek to develop a new analytic center objective for the projection step specialized for hard problems. This objective is going use coefficients that correspond to the analytic center of the polyhedron associated to the LP relaxation, with the intention to drive the search towards regions that contain feasible solutions. An alternative way to tackle hard MIPs is to develop a parallel framework utilizing the strengths of multiple FP variants and using different initialization vectors to search simultaneously in multiple regions for feasible solutions. As a first step in this direction, we aim to incorporate further FP variants and solver interfaces in our implementation. Such an “all-inclusive” implementation serves also the additional purpose of enabling more accurate comparisons and novel combinations of different FP variants, and, of course, promotes further research on the topic.

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## A.1. Test Sets

Our main test set consists of the 283 instances shown in Table A.1. The columns from left to right contain the name of the problem, the numbers of: all variables, binary variables, general integer variables, linear constraints, nonzeros in the constraint matrix, and the objective value of the optimal, or best known, solution.

In the second part of our computational study we conducted experiments regarding Stage 3. Our test set consists of all instances where  $\text{FP}+(3,sv,g,c,\Delta)$  did not terminate within 50 iterations in Stage 1 and 2. In particular, for Xpress as underlying solver we used the 62 instances shown in Table A.2. For CPLEX we used the 60 instances from Table A.3, and for SCIP the 65 instances from Table A.4.

Our ITC 2021 test set consists of three variants of the 45 instances shown in Table A.5. The columns from left to right contain the name of the problem, and the numbers of: all variables, binary variables, general integer variables, linear constraints, and nonzeros in the constraint matrix.

Table A.1.: Main test set

problem	Variables	Binaries	Integers	Constraints	Nonzeros	Objective
10teams	2025	1800	0	230	12150	924.0
30n20b8	18380	11036	62	576	109706	302.0
50v-10	2013	1464	183	233	2745	3311.2
CMS750-4	11697	7196	0	16381	44903	252.0
a1c1s1	3648	192	0	3312	10178	11503.4
academictimetables <sub>small</sub>	28926	28926	0	23294	268350	0.0
af <sub>low</sub> 30a	842	421	0	479	2091	1158.0
af <sub>low</sub> 40b	2728	1364	0	1442	6783	1168.0
air04	8904	8904	0	823	72965	56137.0
air05	7195	7195	0	426	52121	26374.0
app1-1	2480	1225	0	4926	18275	-3.0
app1-2	26871	13300	0	53467	199175	-41.0
arki001	1388	415	96	1048	20439	7580813.0
assign1-5-8	156	130	0	161	3720	212.0

(continued)

Table A.1 continued

problem	Variables	Binaries	Integers	Constraints	Nonzeros	Objective
atlanta-ip	48738	46667	106	21732	257532	90.0
b1c1s1	3872	288	0	3904	11408	24544.2
bab2	147912	147912	0	17245	2027726	-357544.3
bab6	114240	114240	0	29904	1283181	-284248.2
beasleyC3	2500	1250	0	1750	5000	754.0
binkar10-1	2298	170	0	1026	4496	6742.2
blp-ar98	16021	15806	0	1128	200601	6205.2
blp-ic98	13640	13550	0	717	191947	4491.4
bnatt400	3600	3600	0	5614	21698	1.0
bppc4-08	1456	1454	0	111	23964	53.0
brazil3	23968	23874	94	14646	133184	24.0
buildingenergy	154978	0	26287	277594	788969	33283.9
cap6000	6000	6000	0	2176	48243	-2451377.0
cbs-cta	24793	2467	0	10112	64388	0.0
chromaticindex1024-7	73728	73728	0	67583	270324	4.0
chromaticindex512-7	36864	36864	0	33791	135156	4.0
cmflsp50-24-8-8	16392	1392	0	3520	158622	55789389.9
co-100	48417	48417	0	2187	1995817	2639942.1
cod105	1024	1024	0	1024	57344	-12.0
comp07-2idx	17264	17155	109	21235	86577	6.0
comp21-2idx	10863	10792	71	14038	57301	74.0
cost266-UUE	4161	171	0	1446	12312	25148940.6
cryptanalysiskb128n5obj16	48950	46502	1120	98021	292875	0.0
csched007	1758	1457	0	351	6379	351.0
csched008	1536	1284	0	351	5687	173.0
cvs16r128-89	3472	3472	0	4633	12528	-97.0
dano3-3	13873	69	0	3202	79655	576.3
dano3-5	13873	115	0	3202	79655	576.9
dano3mip	13873	552	0	3202	79655	665.6
danoint	521	56	0	664	3232	65.7
decomp2	14387	14379	0	10765	64073	-160.0
disctom	10000	10000	0	399	30000	-5000.0
drayage-100-23	11090	11025	0	4630	41550	103333.9
drayage-25-23	11090	11025	0	4630	41550	101282.6
ds	67732	67732	0	656	1024059	93.5
dws008-01	11096	6608	0	6064	56400	37412.6
eil33-2	4516	4516	0	32	44243	934.0
eilA101-2	65832	65832	0	100	959373	880.9
enlight-hard	200	100	100	100	560	37.0
ex10	17680	17680	0	69608	1162000	100.0
ex9	10404	10404	0	40962	517112	81.0
exp-1-500-5-5	990	250	0	550	1980	65887.0
fast0507	63009	63009	0	507	409349	174.0
fastxgemm-n2r6s0t2	784	48	0	5998	19376	230.0
fhnw-binpack4-48	3710	3605	0	4480	17290	0.0
fiball	34219	33960	258	3707	104792	138.0
fiber	1298	1254	0	363	2944	405935.2
fixnet6	878	378	0	478	1756	3983.0
gen-ip002	41	0	41	24	922	-4783.7
gen-ip054	30	0	30	27	532	6841.0
germanrr	10813	5288	5251	10779	175547	47095869.6
gesa2	1224	240	168	1392	5064	25779856.4
gesa2-o	1224	384	336	1248	3672	25779856.4
gfd-schedulen180f7d50m30k18	227535	160896	1988	457985	1233372	1.0
glass-sc	214	214	0	6119	63918	23.0
glass4	322	302	0	396	1815	1200012600.0
gmu-35-40	1205	1200	0	424	4843	-2406733.4
gmu-35-50	1919	1914	0	435	8643	-2607958.3
graph20-20-1rand	2183	2183	0	5587	19277	-9.0
graphdraw-domain	254	180	20	865	2600	19686.0
h80x6320d	12640	6320	0	6558	31521	6382.1

*(continued)*

Table A.1 continued

problem	Variables	Binaries	Integers	Constraints	Nonzeros	Objective
harp2	2993	2993	0	112	5840	-73899798.8
highschool1-aigio	320404	319686	718	92568	1562168	0.0
hypothyroid-k1	2602	2598	1	5195	433884	-2851.0
ic97p	728	450	73	1046	3138	3942.0
ic97t	703	176	4	319	2070	3942.0
icir97p	2112	1235	422	3314	9942	6325.0
icir97t	2494	262	573	1203	22333	6375.0
irish-electricity	61728	9888	0	104259	523257	3723497.6
irp	20315	20315	0	39	98254	12159.5
istanbul-no-cutoff	5282	30	0	20346	71477	204.1
k1mushroom	8211	8209	1	16419	1697946	-3288.0
lectsched-5-obj	21805	21389	416	38884	239608	24.0
leo1	6731	6730	0	593	131218	404227536.2
leo2	11100	11099	0	593	219959	404077441.1
liu	1156	1089	0	2178	10626	1084.0
lotsize	2985	1195	0	1920	6565	1480195.0
mad	220	200	0	51	2808	0.0
manna81	3321	18	3303	6480	12960	-13164.0
map10	164547	146	0	328818	549920	-495.0
map16715-04	164547	146	0	328818	549920	-111.0
markshare1	62	50	0	6	312	1.0
markshare2	74	60	0	7	434	1.0
markshare-4-0	34	30	0	4	123	1.0
mas74	151	150	0	13	1706	11801.2
mas76	151	150	0	12	1640	40005.1
mc11	3040	1520	0	1920	6080	11689.0
mcsched	1747	1731	0	2107	8088	211913.0
mik-250-20-75-4	270	75	175	195	9270	-52301.0
milo-v12-6-r2-40-1	2688	840	0	5628	14604	326481.1
misc07	260	259	0	212	8619	2810.0
mkc	5325	5323	0	3411	17038	-563.8
mod011	10958	96	0	4480	22254	-54558535.6
modglob	422	98	0	291	968	20740508.1
momentum1	5174	2349	0	42680	103198	109143.5
msc98-ip	21143	20237	53	15850	92918	19839497.0
mushroom-best	8468	8237	118	8580	188735	0.1
mzzv11	10240	9989	251	9499	134603	-21718.0
mzzv42z	11717	11482	235	10460	151261	-20540.0
n2seq36q	22480	22480	0	2565	183292	52200.0
n3div36	22120	22120	0	4484	340740	130800.0
n5-3	2550	0	150	1062	9900	8105.0
neos-1122047	5100	100	0	57791	163640	161.0
neos-1171448	4914	2457	0	13206	131859	-309.0
neos-1171737	2340	1170	0	4179	58620	-195.0
neos-1354092	13702	13282	420	3135	187187	46.0
neos-1445765	20617	2150	0	2147	40230	-17783.0
neos-1456979	4605	4245	180	6770	36440	176.0
neos-1582420	10100	10000	100	10180	24814	91.0
neos-2657525-crna	524	146	378	342	1690	1.8
neos-2746589-doon	50936	50704	224	31530	271072	2008.2
neos-2978193-inde	20800	64	0	396	41600	-2.4
neos-2987310-joes	27837	3051	0	29015	580291	-607702988.3
neos-3004026-krka	17030	16900	130	12545	41860	0.0
neos-3024952-loue	3255	0	3255	3705	17310	26756.0
neos-3046615-murg	274	240	16	498	1266	1600.0
neos-3083819-nubu	8644	0	8644	4725	24048	6307996.0
neos-3216931-puriri	3555	3268	0	5989	91691	71320.0
neos-3381206-awhea	2375	475	1900	479	4275	453.0
neos-3402294-bobin	2904	2616	0	591076	2034888	0.1
neos-3555904-turama	37461	37461	0	146493	793605	-34.7
neos-3627168-kasai	1462	535	0	1655	5158	988585.6

*(continued)*

Table A.1 continued

problem	Variables	Binaries	Integers	Constraints	Nonzeros	Objective
neos-3656078-kumeu	14870	9755	4455	17656	59292	-13172.2
neos-3754480-nidda	253	50	0	402	1488	12941.7
neos-4300652-rahue	33003	20900	0	76992	183616	2.1
neos-4338804-snowy	1344	1260	42	1701	6342	1471.0
neos-4387871-tavua	4004	2000	0	4554	23496	33.4
neos-4413714-turia	190402	190201	0	2303	761756	45.4
neos-4532248-waihi	86842	86841	0	167322	525339	61.6
neos-4647030-tutaki	12600	7000	0	8382	3953388	27265.7
neos-4722843-widden	77723	73349	20	113555	311529	25009.7
neos-4738912-atrato	6216	1120	5096	1947	19521	283627956.6
neos-4763324-toguru	53593	53592	0	106954	266805	1613.0
neos-4954672-berkel	1533	630	0	1848	8007	2612710.0
neos-5049753-cuanza	242736	8304	0	322248	1440672	562.0
neos-5052403-cygnnet	32868	32868	0	38268	4898304	182.0
neos-5093327-huahum	40640	64	0	51840	784768	6260.0
neos-5104907-jarama	345856	9520	0	489818	2053548	935.0
neos-5107597-kakapo	3114	2976	0	6498	19392	3645.0
neos-5188808-nattai	14544	288	0	29452	133686	0.1
neos-5195221-niemur	14546	9792	0	42256	176586	0.0
neos-631710	167056	167056	0	169576	834166	203.0
neos-662469	18235	17907	328	1085	200055	184380.0
neos-787933	236376	236376	0	1897	298320	30.0
neos-827175	32504	21350	0	14187	110790	112.0
neos-848589	550539	747	0	1484	1101078	2351.4
neos-860300	1385	1384	0	850	384329	3201.0
neos-873061	175288	87644	0	93360	350576	113.7
neos-911970	888	840	0	107	3408	54.8
neos-933966	31762	27982	0	12047	180618	318.0
neos-950242	5760	5520	240	34224	104160	4.0
neos-957323	57756	57756	0	3757	499656	-237.8
neos-960392	59376	59376	0	4744	189503	-238.0
neos10	23489	23484	5	46793	251197	-1135.0
neos16	377	336	41	1018	2801	446.0
neos17	535	300	0	486	4931	0.2
neos20	1165	937	30	2446	7428	-434.0
neos5	63	53	0	63	2016	15.0
neos7	1556	434	20	1994	5304	721934.0
neos8	23228	23224	4	46324	313180	-3719.0
net12	14115	1603	0	14021	80384	214.0
netdiversion	129180	129180	0	119589	615282	242.0
nexp-150-20-8-5	20115	17880	0	4620	42465	231.0
nh97p	1180	630	328	1916	5748	1418.0
nh97t	1576	257	361	737	5264	1418.0
noswot	128	75	25	182	735	-41.0
ns1116954	12648	7482	0	131991	410582	0.0
ns1208400	2883	2880	0	4289	81746	2.0
ns1644855	30200	10000	0	40698	2110696	-1524.3
ns1760995	17956	17822	0	615388	1854012	-549.2
ns1830653	1629	1458	0	2932	100933	20622.0
ns1952667	13264	0	13264	41	335643	0.0
nsrand-ipx	6621	6620	0	735	223261	51200.0
nu25-pr12	5868	5832	36	2313	17712	53905.0
nursesched-medium-hint03	34248	34170	78	14062	622800	115.0
nursesched-sprint02	10250	10230	20	3522	204000	58.0
nw04	87482	87482	0	36	636666	16862.0
opm2-z10-s4	6250	6250	0	160633	371240	-33269.0
opt1217	769	768	0	64	1542	-16.0
p200x1188c	2376	1188	0	1388	4752	15078.0
p2756	2756	2756	0	755	8937	3124.0
peg-solitaire-a3	4552	4552	0	4587	28387	1.0
pg	2700	100	0	125	5200	-8674.3

*(continued)*



Table A.1 continued

problem	Variables	Binaries	Integers	Constraints	Nonzeros	Objective
pg5-34	2600	100	0	225	7700	-14339.4
physiciansched3-3	79555	72141	0	266227	1062479	2623271.3
physiciansched6-2	111827	109346	0	168336	480259	49324.0
piperout-08	10399	10237	124	14589	44959	125055.0
piperout-27	11659	11506	110	18442	54662	8124.0
pk1	86	55	0	45	915	11.0
pp08a	240	64	0	136	480	7350.0
pp08aCUTS	240	64	0	246	839	7350.0
proteindesign121hz512p9	159145	159054	91	301	629449	1473.0
proteindesign122trx11p8	127326	127248	78	254	503427	1747.0
protfold	1835	1835	0	2112	23491	-31.0
qap10	4150	4150	0	1820	18200	340.0
qiu	840	48	0	1192	3432	-132.9
rB10-011000	4456	4320	136	1667	16517	19449.0
rB10-011001	4456	4320	136	1677	19397	22891.7
rB11-010000	12376	12210	166	3792	35240	34832.0
rB11-110001	12431	12265	166	8148	52678	45594.3
rB12-111111	9109	8778	331	8978	58703	40881.6
rC10-001000	3117	2993	124	1293	11751	11460.0
rC10-100001	5864	5740	124	7596	31452	19251.5
rC11-010100	12321	12155	166	4010	46955	30642.2
rC11-011100	6491	6325	166	2367	30472	20889.0
rC12-100000	17299	17112	187	21550	82834	38608.0
rC12-111100	8619	8432	187	10842	57104	38389.3
radiationm18-12-05	40623	14688	11247	40935	96149	17566.0
radiationm40-10-02	172013	62400	47213	173603	406825	155328.0
rail01	117527	117527	0	46843	392086	-70.6
rail02	270869	270869	0	95791	756228	-200.4
rail507	63019	63009	0	509	468878	174.0
ran14x18-disj-8	504	252	0	447	10277	3712.0
rd-rplusc-21	622	457	0	125899	852384	165395.3
reblock115	1150	1150	0	4735	13724	-36800603.2
rmatr100-p10	7359	100	0	7260	21877	423.0
rmatr200-p5	37816	200	0	37617	113048	4521.0
rocI-4-11	6839	4576	1016	10883	27383	-6020203.0
rocII-5-11	11523	11341	0	26897	303291	-6.7
roi2alpha3n4	6816	6642	0	1251	878812	-63.2
roi5alpha10n8	106150	105950	0	4665	2370224	-52.3
roll3000	1166	246	492	2295	29386	12890.0
rout	556	300	15	291	2431	1077.6
s100	364417	364417	0	14733	1777917	-0.2
s250r10	273142	273139	0	10962	1318607	-0.2
satellites2-40	35378	34324	0	20916	283668	-19.0
satellites2-60-fs	35378	34324	0	16516	125048	-19.0
savsched1	328575	252731	0	295989	1770507	3217.7
sct2	5885	2540	0	2151	23643	-231.0
set1ch	712	240	0	492	1412	54537.8
seymour	1372	1372	0	4944	33549	423.0
seymour1	1372	451	0	4944	33549	410.8
sing326	55156	40010	0	50781	268173	7753674.9
sing44	59708	43524	0	54745	281260	8128831.2
snp-02-004-104	228350	167	167	126512	463941	586803238.7
sorrell3	1024	1024	0	169162	338324	-16.0
sp150x300d	600	300	0	450	1200	69.0
sp97ar	14101	14101	0	1761	290968	660705645.8
sp98ar	15085	15085	0	1435	426148	529740623.2
splice1k1	3253	3252	1	6505	1761016	-394.0
square41	62234	62197	37	40160	13566426	15.0
square47	95030	94987	43	61591	27329856	16.0
supportcase10	14770	14770	0	165684	555082	7.0
supportcase12	799616	0	200	166781	2334437	-7559.5

*(continued)*

Table A.1 continued

problem	Variables	Binaries	Integers	Constraints	Nonzeros	Objective
supportcase18	13410	13410	0	240	28920	48.0
supportcase26	436	396	0	870	2492	1745.1
supportcase33	20203	20095	101	20489	211915	-345.0
supportcase40	16440	2000	0	38192	104420	24256.3
supportcase42	19466	0	1026	18439	435653	7.8
supportcase6	130052	130051	1	771	584976	51906.5
supportcase7	138844	451	14	6532	2845545	-1132.2
swath	6805	6724	0	884	34965	467.4
swath1	6805	2306	0	884	34965	379.1
swath3	6805	2706	0	884	34965	397.8
t1717	73885	73885	0	551	325689	161330.0
tbfp-network	72747	72747	0	2436	215837	24.2
thor50dday	106261	53130	0	53360	212060	40417.0
timtab1	397	64	94	171	829	764772.0
timtab2	675	113	164	294	1482	1096560.0
tr12-30	1080	360	0	750	2508	130596.0
traininstance2	12890	5266	2602	15603	41531	71820.0
traininstance6	10218	4143	2056	12309	32785	28290.0
trento1	7687	6415	0	1265	93571	5189487.0
triptim1	30055	20451	9592	15706	515436	22.9
uccase12	62529	9072	0	121161	419447	11507.4
uccase9	33242	7905	0	49565	332316	10993.1
uct-subprob	2256	379	0	1973	10147	314.0
unitcal-7	25755	2856	0	48939	127595	19635558.2
var-smallemery-m6j6	5608	5606	0	13416	850623	-149.4
vpm2	378	168	0	234	917	13.8
wachplan	3361	3360	1	1553	89361	-8.0

Table A.2.: 62 instances where  $FP+(3,sv,g,c,\Delta)$  with Xpress requires more than 50 iterations in Stage 1 and 2.

30n20b8	neos-3381206-awhea	piperout-27
academicmetablesmall	neos-3656078-kumeu	proteindesign121hz512p9
arki001	neos-4300652-rahue	rB12-111111
bab2	neos-4338804-snowy	rC10-100001
cmflsp50-24-8-8	neos-4387871-tavua	rC12-100000
csched007	neos-4532248-waihi	radiationm18-12-05
csched008	neos-4722843-widden	radiationm40-10-02
dws008-01	neos-5049753-cuanza	rd-rplusc-21
germanrr	neos-5104907-jarama	rocI-4-11
ic97p	neos-5107597-kakapo	rocII-5-11
ic97t	neos-5114902-kasavu	satellites2-60-fs
icir97p	neos-848589	supportcase26
icir97t	neos-960392	supportcase33
lectsched-5-obj	neos16	swath
momentum1	neos20	swath1
mushroom-best	nh97p	timtab1
neos-1456979	nh97t	timtab2
neos-1582420	ns1830653	traininstance2
neos-2746589-doon	physiciansched3-3	traininstance6
neos-3024952-loue	physiciansched6-2	unitcal_7
neos-3216931-puriri	piperout-08	

Table A.3.: 60 instances where  $FP+(3,sv,g,c,\Delta)$  with CPLEX requires more than 50 iterations in Stage 1 and 2.

30n20b8	neos-1456979	physiciansched6-2
CMS750_4	neos-1582420	piperout-08
academictimetablesmall	neos-2746589-doon	piperout-27
arki001	neos-2987310-joes	proteindesign122trx11p8
bab2	neos-3024952-loue	rB12-111111
bab6	neos-3216931-puriri	rC10-100001
cmflsp50-24-8-8	neos-3381206-awhea	radiationm18-12-05
csched007	neos-3555904-turama	radiationm40-10-02
dws008-01	neos-4300652-rahue	rd-rplusc-21
eilA101-2	neos-4338804-snowy	rocI-4-11
glass4	neos-4387871-tavua	rocII-5-11
ic97p	neos-4532248-waihi	satellites2-40
ic97t	neos-5049753-cuanza	satellites2-60-fs
icir97p	neos-5107597-kakapo	swath
icir97t	neos-848589	swath1
irish-electricity	neos20	timtab1
lectsched-5-obj	nh97p	timtab2
markshare1	nh97t	traininstance2
markshare_4.0	ns1830653	traininstance6
momentum1	physiciansched3-3	unitcal_7

Table A.4.: 65 instances where  $FP+(3,sv,g,c,\Delta)$  with SCIP requires more than 50 iterations in Stage 1 and 2.

10teams	neos-1582420	piperout-27
30n20b8	neos-2657525-crna	proteindesign121hz512p9
arki001	neos-2746589-doon	proteindesign122trx11p8
bab2	neos-3046615-murg	rB12-111111
bab6	neos-3216931-puriri	rC10-100001
comp21-2idx	neos-3381206-awhea	radiationm18-12-05
csched007	neos-3656078-kumeu	radiationm40-10-02
csched008	neos-4338804-snowy	rd-rplusc-21
danoint	neos-4387871-tavua	reblock115
eilA101-2	neos-4532248-waihi	rocI-4-11
fastxgemm-n2r6s0t2	neos-4722843-widden	rocII-5-11
fiball	neos-5107597-kakapo	roll3000
hypothyroid-k1	neos-848589	supportcase42
ic97p	neos16	swath
ic97t	neos20	swath1
icir97p	nh97p	swath3
icir97t	nh97t	timtab1
lectsched-5-obj	ns1208400	timtab2
milo-v12-6-r2-40-1	ns1830653	traininstance2
momentum1	physiciansched3-3	traininstance6
mushroom-best	physiciansched6-2	unitcal_7
neos-1456979	piperout-08	

Table A.5.: ITC 2021 test set

problem	Variables	Binaries	Integers	Constraints	Nonzeros
Early 1	15799	15104	464	16640	334104
Early 2	10973	8144	464	12670	315013
Early 3	11825	8144	464	12760	301085
Early 4	21957	21690	0	12833	304627
Early 5	25606	21690	0	17670	509636
Early 6	24870	21708	594	27164	669879
Early 7	26208	21690	0	17524	496789
Early 8	16298	11610	594	17199	450336
Early 9	15098	11610	594	15995	387686
Early 10	31776	29980	0	20388	589835
Early 11	34895	29980	0	23317	683719
Early 12	16635	15920	0	5189	235722
Early 13	20092	15920	0	7662	308022
Early 14	16924	15940	740	17981	444722
Early 15	21901	15940	740	24556	743975
Middle 1	16080	15088	0	9894	272106
Middle 2	19230	15088	0	14084	411557
Middle 3	19680	15104	464	21498	537953
Middle 4	11760	11592	0	3176	124352
Middle 5	12913	11610	594	14076	319937
Middle 6	25173	21690	0	17187	457927
Middle 7	22165	21690	0	13454	341442
Middle 8	15056	11592	0	6836	260680
Middle 9	15557	11610	594	17025	445222
Middle 10	16634	15920	0	3787	179311
Middle 11	20909	15940	740	23706	716075
Middle 12	31610	30000	740	33570	788780
Middle 13	30329	29980	0	18007	459991
Middle 14	21493	15940	740	23994	699216
Middle 15	32730	29980	0	19592	477483
Late 1	9607	8128	0	10921	269272
Late 2	12117	8128	0	6810	280336
Late 3	17243	15088	0	18451	423591
Late 4	21723	21690	0	12533	296757
Late 5	13103	11592	0	15395	422838
Late 6	21848	21690	0	12718	312508
Late 7	24257	21690	0	15527	426024
Late 8	25213	21690	0	16047	409837
Late 9	16118	11592	0	18180	488816
Late 10	30673	29980	0	19288	553873
Late 11	20227	15920	0	21462	563882
Late 12	31532	29980	0	19951	595250
Late 13	31062	29980	0	33660	832455
Late 14	21670	15920	0	24254	707189
Late 15	17420	15920	0	18471	461234

## A.2. Results for Stage 1 and 2 Configurations

From Table A.6 to Table A.25 we present detailed results for FP and its variants with a modified projection step. In all experiments we use Xpress as underlying solver. For each instance and for each FP variant, we report the termination stage for the three runs with different random seeds, and the shifted geometric mean of four figures: gap percentage w.r.t the best known solution ( $\text{gap}(\%)$ ), running time ( $\text{time}(\text{s})$ ), number of iterations ( $\text{iterations}$ ), and number of restarts

(restarts). In tables presenting the results of FP variants we also include an additional column that denotes the percentage of improvement (improvement(%)) of the four figures when compared to FP. Note that a negative value denotes a deterioration percentage. Moreover, in blue boldface we highlight values that are at least 10% better from the corresponding values found by FP, and in red italics values that are at least 10% worse. For the gap and running time, we highlight values only for instances solved with all three seeds by both the FP variant and FP. For the iterations and restarts, we highlight if in addition both the FP variant and FP terminate solely in Stage 1 or 2. On the last rows of each table we show the geometric means for the primal gap, running time, number of iterations, and restarts, for both FP and the tested variant. The geometric means of the primal gap and running time are computed over all instances of our test set that both algorithms found solutions in all three runs. Further, the geometric means of the number of iterations and restarts are computed over instances that were solved solely in Stage 1 and 2. The number of used instances is written in the parenthesis over the geometric means. In Table A.26 to Table A.29 we present similar results with CPLEX as underlying solver, and in Table A.30 to Table A.33 with SCIP.

Table A.6.: Performance of FP

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
10teams	1/2/0	12.1	12.2	159.6	1.2
30n20b8	0/3/0	462.2	5.7	167.0	28.9
50v-10	0/3/0	124.7	0.3	23.0	0.3
CMS750-4	3/0/0	53.0	4.1	65.1	12.0
a1c1s1	3/0/0	52.8	0.4	31.3	1.3
academicimetablesmall	0/0/1	inf <sup>(1)</sup>	770.0	1154.0	0.0
aflow30a	3/0/0	131.6	0.1	33.5	2.0
aflow40b	3/0/0	207.3	0.3	32.0	1.5
air04	3/0/0	0.1	2.6	6.6	0.0
air05	3/0/0	4.1	0.8	4.0	0.0
app1-1	3/0/0	3.1	0.5	34.6	4.0
app1-2	3/0/0	43.9	10.7	51.8	15.3
arki001	0/1/2	2.9	20.7	804.1	186.4
assign1-5-8	3/0/0	1.9	0.1	22.3	0.0
atlanta-ip	3/0/0	18.0	16.9	25.8	0.6
b1c1s1	3/0/0	161.3	0.5	33.7	3.6
bab2	1/1/1	25.5	314.1	173.0	23.5
bab6	2/1/0	23.7	104.4	87.7	15.3
beasleyC3	3/0/0	11.6	0.2	35.0	4.8
binkar10-1	3/0/0	4.0	0.1	15.7	0.0
blp-ar98	3/0/0	71.3	2.0	16.9	0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0
bnatt400	0/0/3	0.0	212.8	847.3	0.0
bppc4-08	3/0/0	51.6	1.2	62.3	9.3
brazil3	0/3/0	634.5	21.1	21.4	0.0
buildingenergy	0/3/0	1.1	696.7	11.7	0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0
cbs-cta	3/0/0	0.0	2.7	40.0	10.0
chromaticindex1024-7	3/0/0	0.0	54.8	3.0	0.0
chromaticindex512-7	3/0/0	0.0	45.0	2.0	0.0
cmflsp50-24-8-8	0/0/3	19.5	167.5	1050.2	294.6
co-100	3/0/0	302.8	6.1	15.6	0.0
cod105	3/0/0	100.0	1.8	1.0	0.0

(continued)

Table A.6 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
comp07-2idx	0/3/0	3426.9	6.2	24.0	0.0
comp21-2idx	0/3/0	426.9	4.6	25.1	0.0
cost266-UUE	3/0/0	35.1	0.4	23.5	0.3
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-
csched007	1/0/2	69.0	6.1	382.5	49.4
csched008	1/2/0	9.8	1.7	152.0	24.0
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0
dano3-3	3/0/0	0.0	18.7	16.2	0.0
dano3-5	3/0/0	0.2	44.0	30.1	0.9
dano3mip	3/0/0	17.2	280.2	70.6	18.3
danoint	3/0/0	651.4	4.0	111.5	41.2
disctom	3/0/0	0.0	1.3	2.0	0.0
drayage-100-23	3/0/0	5.6	0.3	13.0	0.0
drayage-25-23	3/0/0	10.2	0.4	16.4	0.0
ds	3/0/0	4945.0	6.0	1.0	0.0
dws008-01	0/0/3	95.9	74.6	819.6	235.7
eil33-2	3/0/0	222.3	0.1	1.0	0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0
enlight-hard	0/0/1	0.0 <sup>(1)</sup>	3.0	903.0	499.0
exp-1-500-5-5	3/0/0	75.4	0.1	26.9	0.0
fast0507	3/0/0	25.0	0.9	1.0	0.0
fastxgemm-n2r6s0t2	3/0/0	907.2	0.4	20.3	0.0
fhnw-binpack4-48	0/0/0	-	-	-	-
fiball	0/3/0	17.2	7.0	56.0	4.6
fiber	3/0/0	153.6	0.1	14.9	0.0
fixnet6	3/0/0	42.6	0.1	31.0	1.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0
gen-ip054	0/3/0	10.5	0.1	2.9	0.0
germanrr	0/3/0	4.1	11.7	50.8	5.9
gesa2	0/3/0	2.4	0.2	20.4	0.0
gesa2-o	0/3/0	20.0	0.2	35.6	1.5
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-
glass-sc	3/0/0	13.4	0.6	1.0	0.0
glass4	3/0/0	681.5	0.3	104.2	32.2
gmu-35-40	3/0/0	6.5	0.1	14.0	0.0
gmu-35-50	3/0/0	12.2	0.3	31.4	1.0
graph20-20-1rand	3/0/0	14.0	4.1	31.3	0.4
graphdraw-domain	0/3/0	28.8	0.3	60.7	10.4
h80x6320d	3/0/0	22.0	1.2	32.0	1.9
harp2	3/0/0	12.4	0.1	12.7	0.0
highschool1-aigio	0/3/0	inf	688.6	15.3	0.0
hypothyroid-k1	3/0/0	0.0	4.8	1.0	0.0
ic97p	0/0/3	15.4	5.1	886.9	205.4
ic97t	0/0/3	12.4	3.9	1266.4	311.2
icir97p	0/0/3	22.9	21.6	1139.9	215.7
icir97t	0/3/0	15.7	4.4	210.5	128.8
irish-electricity	3/0/0	6.0	19.4	24.2	0.3
irp	3/0/0	3.8	0.3	3.4	0.0
istanbul-no-cutoff	3/0/0	36.0	6.4	22.0	0.0
k1mushroom	3/0/0	18.2	39.8	1.0	0.0
lectsched-5-obj	0/0/3	2245.5	84.0	908.5	7.0
leo1	3/0/0	50.7	0.1	1.0	0.0
leo2	3/0/0	45.2	0.2	1.0	0.0
liu	3/0/0	674.7	1.1	90.0	56.6
lotsize	3/0/0	70.7	0.5	44.9	10.5
mad	3/0/0	12358.1	0.1	14.7	0.0
manna81	0/3/0	13.9	0.1	2.6	0.0
map10	3/0/0	44.7	49.9	35.8	3.2
map16715-04	3/0/0	89.2	56.9	46.3	9.1
markshare1	3/0/0	36348.2	0.1	1.0	0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0

(continued)

Table A.6 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0
mas74	0/3/0	475.9	0.2	90.0	14.6
mas76	0/3/0	105.8	0.2	90.7	21.5
mc11	3/0/0	108.2	0.4	42.6	12.3
mcsched	3/0/0	12.9	0.5	3.6	0.0
mik-250-20-75-4	0/3/0	61.1	0.2	38.3	4.5
milo-v12-6-r2-40-1	3/0/0	150.3	0.9	42.0	12.0
misc07	3/0/0	28.6	0.1	20.1	0.0
mkc	0/3/0	66.5	0.1	2.0	0.0
mod011	3/0/0	14.0	0.3	19.6	0.0
modglob	3/0/0	105.9	0.1	31.3	1.3
momentum1	0/3/0	193.4	39.5	557.9	353.1
msc98-ip	3/0/0	15.5	6.3	30.7	0.6
mushroom-best	0/3/0	9.17e06	13.6	40.0	1.7
mzzv11	0/3/0	20.1	4.2	19.3	0.0
mzzv42z	0/3/0	31.0	4.9	23.8	0.3
n2seq36q	3/0/0	29.9	0.4	1.0	0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0
n5-3	0/3/0	9.4	0.3	20.4	0.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0
neos-1171448	3/0/0	0.9	4.9	26.4	0.6
neos-1171737	3/0/0	3.9	1.6	29.6	0.6
neos-1354092	0/3/0	18.1	176.3	37.6	0.0
neos-1445765	3/0/0	35.4	0.8	5.6	0.0
neos-1456979	0/2/1	149.9	40.4	462.4	96.5
neos-1582420	0/3/0	69.0	1.5	79.5	9.4
neos-2657525-crna	0/3/0	1016.4	0.2	41.8	2.0
neos-2746589-doon	0/2/1	34.9	138.1	248.1	31.3
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0
neos-2987310-joes	2/1/0	0.3	9.5	54.3	14.8
neos-3004026-krka	0/0/3	0.0	109.0	1285.7	3.6
neos-3024952-loue	0/0/3	813.1	79.9	1414.2	27.8
neos-3046615-murg	0/3/0	10898.5	0.2	94.3	65.6
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0
neos-3216931-puriri	0/0/3	120.9	458.4	1096.3	0.0
neos-3381206-awhea	0/0/3	4.9	18.3	1054.0	1.1
neos-3402294-bobin	3/0/0	429.3	20.1	19.1	0.0
neos-3555904-turama	3/0/0	2.0	78.2	31.4	0.4
neos-3627168-kasai	3/0/0	1.5	0.1	20.4	0.0
neos-3656078-kumeu	0/0/3	30.8	140.3	1041.5	0.9
neos-3754480-nidda	3/0/0	365.6	0.2	67.7	13.6
neos-4300652-rahue	0/1/2	265.8	412.9	354.7	0.3
neos-4338804-snowy	0/3/0	1.14e05	0.8	100.5	28.0
neos-4387871-tavua	0/1/2	755.0	22.9	802.1	427.4
neos-4413714-turia	3/0/0	43.9	79.9	79.7	13.0
neos-4532248-waihi	0/1/2	949.4	489.0	439.7	36.1
neos-4647030-tutaki	3/0/0	22.0	17.5	17.7	0.0
neos-4722843-widden	0/3/0	197.7	55.1	92.4	25.6
neos-4738912-atrato	0/3/0	12.0	0.3	12.4	0.0
neos-4763324-toguru	3/0/0	59.2	21.1	23.7	0.0
neos-4954672-berkel	3/0/0	54.7	0.1	32.0	1.3
neos-5049753-cuanza	1/2/0	75.6	770.4	325.6	72.0
neos-5052403-cygnat	3/0/0	1.3	42.1	2.3	0.0
neos-5093327-huahum	3/0/0	913.3	13.4	120.7	86.6
neos-5104907-jarama	0/0/1	93.7 <sup>(1)</sup>	3514.6	817.0	33.0
neos-5107597-kakapo	3/0/0	39300.2	1.8	123.3	94.9
neos-5114902-kasavu	0/1/0	50.1 <sup>(1)</sup>	3054.2	124.0	18.0
neos-5188808-nattai	3/0/0	4012.9	5.7	26.7	0.0
neos-5195221-niemur	3/0/0	767.9	7.4	18.7	0.0
neos-631710	3/0/0	149.4	2.5	1.0	0.0
neos-662469	0/3/0	223.1	6.4	19.3	0.7

(continued)

Table A.6 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
neos-787933	0/3/0	0.0	0.1	1.0	0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0
neos-848589	3/0/0	2.96e05	103.3	69.3	20.7
neos-860300	3/0/0	57.0	0.4	4.0	0.0
neos-873061	3/0/0	61.2	25.7	31.7	1.6
neos-911970	3/0/0	132.0	0.2	50.0	6.0
neos-933966	3/0/0	224.1	1.6	9.4	0.0
neos-950242	3/0/0	128.3	6.7	21.8	0.4
neos-957323	3/0/0	6.6	2.1	1.9	0.0
neos-960392	3/0/0	2.3	20.2	61.9	2.1
neos10	0/3/0	64.5	0.1	2.9	0.0
neos16	0/0/3	1.4	9.3	1168.7	2.6
neos17	3/0/0	290.2	0.2	31.7	1.6
neos20	0/0/3	45.7	9.8	1181.7	81.4
neos5	3/0/0	41.6	0.1	3.8	0.0
neos7	0/3/0	11.0	0.2	25.0	0.0
neos8	0/3/0	20.7	0.1	2.6	0.0
net12	3/0/0	38.3	4.3	25.7	0.0
netdiversion	3/0/0	86.4	74.9	9.6	0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0
nh97p	0/0/3	10.2	13.6	1092.4	259.0
nh97t	0/0/3	10.6	12.8	1091.7	326.6
noswot	0/3/0	9.6	0.1	34.3	1.3
ns1116954	1/1/1	0.0	471.8	467.3	3.2
ns1208400	1/2/0	0.0	90.1	395.5	0.3
ns1644855	3/0/0	0.5	390.6	34.5	1.7
ns1760995	3/0/0	14.9	84.6	80.5	2.9
ns1830653	2/1/0	164.2	4.4	58.8	1.0
ns1952667	0/0/0	-	-	-	-
nsrand-ipx	3/0/0	37.0	0.1	1.0	0.0
nu25-pr12	0/3/0	3.3	0.3	19.0	0.0
nursesched-medium-hint03	0/3/0	786.4	13.9	11.4	0.0
nursesched-sprint02	0/3/0	55.2	1.9	9.3	0.0
nw04	3/0/0	3.9	2.0	8.0	0.0
opm2-z10-s4	3/0/0	94.2	27.3	1.0	0.0
opt1217	3/0/0	7.8	0.1	36.3	2.3
p200x1188c	3/0/0	3.9	0.2	31.0	1.0
p2756	0/3/0	82.1	0.1	5.0	0.0
peg-solitaire-a3	0/0/2	0.0 <sup>(2)</sup>	481.9	1220.8	277.6
pg	3/0/0	15.5	0.3	51.7	19.2
pg5-34	3/0/0	7.1	0.4	52.0	13.6
physiciansched3-3	3/0/0	8.7	54.5	46.0	1.0
physiciansched6-2	0/2/1	4.9	84.4	740.2	34.8
piperout-08	0/0/3	394.9	69.2	1710.9	33.3
piperout-27	0/0/3	228.4	66.0	1196.9	17.6
pk1	3/0/0	1191.8	0.2	58.0	8.9
pp08a	3/0/0	58.4	0.1	15.6	0.0
pp08aCUTS	3/0/0	35.1	0.1	12.0	0.0
proteindesign121hz512p9	0/3/0	2.4	5.0	24.4	0.3
proteindesign122trx11p8	0/3/0	1.1	1.0	4.0	0.0
protfold	3/0/0	66.0	8.4	37.8	0.0
qap10	3/0/0	19.4	13.7	2.0	0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0
rB10-011000	3/0/0	240.2	0.5	25.3	0.0
rB10-011001	3/0/0	204.1	0.5	26.3	0.0
rB11-010000	3/0/0	288.7	1.3	30.0	0.6
rB11-110001	3/0/0	207.5	2.6	23.3	0.3
rB12-111111	0/2/1	89.9	46.4	574.8	3.2
rC10-001000	3/0/0	275.1	0.2	27.9	0.0
rC10-100001	3/0/0	408.4	4.9	101.5	0.8
rC11-010100	3/0/0	347.0	0.2	1.0	0.0

(continued)



Table A.6 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
rC11-011100	3/0/0	480.5	0.2	1.0	0.0
rC12-100000	3/0/0	321.8	5.1	36.4	0.8
rC12-111100	3/0/0	194.9	0.3	1.0	0.0
radiationm18-12-05	0/3/0	152.1	1.8	68.3	3.6
radiationm40-10-02	0/3/0	431.1	16.2	143.8	9.0
rail01	3/0/0	31.0	1280.3	11.9	0.0
rail02	0/0/0	-	-	-	-
rail507	3/0/0	23.3	1.2	1.0	0.0
ran14x18-disj-8	3/0/0	16.6	0.3	22.8	0.3
rd-rplusc-21	0/0/3	58.1	36.2	866.6	360.6
reblock115	3/0/0	11.2	1.6	55.4	6.2
rmatr100-p10	3/0/0	29.5	0.6	2.3	0.0
rmatr200-p5	3/0/0	19.5	14.1	2.0	0.0
rocl-4-11	0/0/3	69.2	21.2	932.1	103.8
rocl1-5-11	2/1/0	90.4	8.4	156.1	52.6
roi2alpha3n4	3/0/0	62.4	33.3	34.3	1.6
roi5alpha10n8	3/0/0	60.1	446.6	29.0	0.0
roll3000	0/3/0	26.2	1.1	48.4	4.5
rout	0/3/0	49.5	0.2	35.2	1.7
s100	3/0/0	1.7	302.7	6.6	0.0
s250r10	3/0/0	0.1	53.4	2.0	0.0
satellites2-40	3/0/0	245.4	44.2	34.9	2.7
satellites2-60-fs	3/0/0	89.5	22.6	34.9	2.7
savsched1	0/3/0	7.9	190.1	12.3	0.0
sct2	3/0/0	29.2	0.6	26.1	0.6
set1ch	3/0/0	85.6	0.1	31.0	1.0
seymour	3/0/0	12.7	0.7	1.0	0.0
seymour1	3/0/0	1.4	2.7	7.6	0.0
sing326	3/0/0	10.6	24.7	34.0	1.6
sing44	3/0/0	7.4	26.4	38.5	3.8
snp-02-004-104	0/3/0	1.7	19.7	33.6	1.9
sorrell3	3/0/0	76.3	0.9	1.0	0.0
sp150x300d	3/0/0	2.9	0.1	31.3	1.3
sp97ar	3/0/0	26.6	0.9	2.2	0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0
splice1k1	3/0/0	98.6	62.1	13.0	0.0
square41	0/3/0	6.7	1220.9	10.0	0.0
square47	0/0/0	-	-	-	-
supportcase10	3/0/0	170.3	110.1	13.6	0.0
supportcase12	0/3/0	1.8	14.6	21.0	0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0
supportcase26	3/0/0	9385.9	0.2	89.7	63.3
supportcase33	0/3/0	64.5	13.8	121.3	14.5
supportcase40	3/0/0	17.6	4.2	16.6	0.0
supportcase42	0/3/0	24.4	4.2	11.6	0.0
supportcase6	3/0/0	0.4	13.3	12.0	0.0
supportcase7	3/0/0	14.3	8.3	26.0	0.0
swath	0/3/0	181.6	13.5	187.8	59.6
swath1	2/1/0	60.4	2.3	62.2	15.7
swath3	3/0/0	33.2	1.5	42.9	3.2
t1717	3/0/0	179.2	126.3	43.5	0.0
tbfp-network	3/0/0	199.5	22.4	14.0	0.0
thor50dday	3/0/0	257.8	7.2	24.5	1.7
timtab1	0/3/0	55.5	0.6	113.7	27.9
timtab2	0/1/2	73.6	5.8	791.4	270.5
tr12-30	3/0/0	72.9	0.2	31.7	1.6
traininstance2	0/3/0	243.6	3.3	649.6	68.6
traininstance6	0/2/1	461.6	1.2	305.9	42.1
trento1	3/0/0	187.1	8.0	9.3	0.0
triptim1	0/3/0	0.1	23.3	4.0	0.0
uccase12	3/0/0	1.9	10.3	15.6	0.0

(continued)

Table A.6 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
uccase9	2/0/1	5608.9	57.9	189.6	73.0
uct-subprob	3/0/0	12.4	0.6	7.7	0.0
unitcal-7	0/0/3	26.8	137.7	991.6	145.9
var-smallemery-m6j6	3/0/0	256.3	24.0	67.5	10.1
vpm2	3/0/0	45.0	0.1	20.4	0.0
wachplan	0/3/0	0.0	3.0	26.5	0.0

Table A.7.: Performance of FP+(2,1,g)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	3/0/0	<b>6.6</b>	<b>3.4</b>	<b>53.8</b>	<b>0.3</b>	45.5/72.1/66.3/75.0
30n20b8	0/3/0	<b>410.7</b>	<b>10.3</b>	<b>348.9</b>	<b>90.0</b>	11.1/-44.7/-52.1/-67.9
50v-10	0/3/0	138.2	0.3	21.7	0.3	-9.8/0.0/5.7/0.0
CMS750-4	3/0/0	<b>73.3</b>	<b>5.7</b>	<b>94.7</b>	<b>20.0</b>	-27.7/-28.1/-31.3/-40.0
a1c1s1	3/0/0	<b>33.9</b>	<b>0.5</b>	31.3	1.3	35.8/-20.0/0.0/0.0
academictimetablesmall	0/0/3	inf	544.2	799.7	0.6	-/-/-/-
aflow30a	3/0/0	<b>109.7</b>	0.1	31.3	<b>1.3</b>	16.6/0.0/6.6/35.0
aflow40b	3/0/0	<b>142.6</b>	0.3	31.3	<b>1.1</b>	31.2/0.0/2.2/26.7
air04	3/0/0	<b>1.0</b>	<b>2.9</b>	<b>9.6</b>	0.0	-90.0/-10.3/-31.2/0.0
air05	3/0/0	<b>2.4</b>	<b>1.1</b>	<b>7.3</b>	0.0	41.5/-27.3/-45.2/0.0
app1-1	3/0/0	<b>42.0</b>	<b>0.6</b>	35.5	4.1	-92.6/-16.7/-2.5/-2.4
app1-2	3/0/0	43.1	<b>12.0</b>	<b>58.0</b>	16.9	1.8/-10.8/-10.7/-9.5
arki001	0/1/2	2.8	<b>16.1</b>	671.3	145.2	3.4/22.2/16.5/22.1
assign1-5-8	3/0/0	<b>4.3</b>	0.1	24.1	0.0	-55.8/0.0/-7.5/0.0
atlanta-ip	3/0/0	<b>10.5</b>	<b>15.1</b>	<b>18.3</b>	<b>0.0</b>	41.7/10.7/29.1/100.0
b1c1s1	3/0/0	<b>220.3</b>	0.5	33.7	3.6	-26.8/0.0/0.0/0.0
bab2	1/1/1	<b>13.9</b>	<b>391.0</b>	240.7	25.9	45.5/-19.7/-28.1/-9.3
bab6	1/0/2	<b>13.6</b>	<b>283.0</b>	349.5	79.4	42.6/-63.1/-74.9/-80.7
beasleyC3	3/0/0	11.1	0.2	35.7	<b>5.6</b>	4.3/0.0/-2.0/-14.3
binkar10-1	3/0/0	3.9	0.1	<b>7.7</b>	0.0	2.5/0.0/51.0/0.0
blp-ar98	3/0/0	72.8	<b>2.4</b>	<b>19.8</b>	0.0	-2.1/-16.7/-14.6/0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/2	0.0	191.9	735.8	0.0	-/-/-/-
bppc4-08	3/0/0	<b>280.1</b>	1.1	62.0	<b>6.3</b>	-81.6/8.3/0.5/32.3
brazil3	0/3/0	<b>378.2</b>	<b>17.4</b>	21.3	0.0	40.4/17.5/0.5/0.0
buildingenergy	0/3/0	1.1	<b>594.3</b>	11.0	0.0	0.0/14.7/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	inf	2.8	40.3	10.3	-100.0/-3.6/-0.7/-2.9
chromaticindex1024-7	3/0/0	0.0	54.2	<b>2.3</b>	0.0	0.0/1.1/23.3/0.0
chromaticindex512-7	3/0/0	0.0	44.8	2.0	0.0	0.0/0.4/0.0/0.0
cmflsp50-24-8-8	1/1/1	<b>17.3</b>	<b>37.6</b>	256.9	71.8	11.3/77.6/75.5/75.6
co-100	3/0/0	313.2	6.4	16.8	0.0	-3.3/-4.7/-7.1/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	<b>3921.1</b>	6.8	<b>28.0</b>	0.0	-12.6/-8.8/-14.3/0.0
comp21-2idx	0/3/0	413.1	4.5	26.7	0.0	3.2/2.2/-6.0/0.0
cost266-UUE	3/0/0	32.7	<b>0.5</b>	<b>29.5</b>	<b>0.6</b>	6.8/-20.0/-20.3/-50.0
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/2/1	<b>80.3</b>	<b>8.6</b>	829.1	177.4	-14.1/-29.1/-53.9/-72.2
csched008	1/2/0	9.4	<b>1.5</b>	159.6	<b>35.7</b>	4.1/11.8/-4.8/-32.8
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	17.8	<b>18.0</b>	0.0	0.0/4.8/-10.0/0.0
dano3-5	3/0/0	<b>0.1</b>	<b>35.4</b>	31.5	<b>1.1</b>	50.0/19.5/-4.4/-18.2
dano3mip	3/0/0	<b>10.6</b>	<b>171.2</b>	70.7	17.6	38.4/38.9/-0.1/3.8
danooint	2/1/0	<b>168.1</b>	<b>2.6</b>	<b>91.9</b>	<b>30.0</b>	74.2/35.0/17.6/27.2
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	5.6	<b>0.4</b>	13.3	0.0	0.0/-25.0/-2.3/0.0
drayage-25-23	3/0/0	<b>14.5</b>	<b>0.6</b>	<b>21.2</b>	0.0	-29.7/-33.3/-22.6/0.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0

(continued)

Table A.7 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
dws008-01	0/0/3	<b>77.9</b>	72.7	832.1	252.6	18.8/2.5/-1.5/-6.7
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.0	1.0	0.0	0.0/9.1/0.0/0.0
enlight-hard	0/0/2	0.0	3.2	740.3	235.9	-/-/-/-
exp-1-500-5-5	3/0/0	<b>51.8</b>	0.1	25.7	0.0	31.3/0.0/4.5/0.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>530.7</b>	0.4	<b>26.7</b>	<b>0.9</b>	41.5/0.0/-24.0/-100.0
fhnw-binpack4-48	0/0/1	0.0	55.2	1528.0	222.0	-/-/-/-
fiball	0/3/0	<b>14.4</b>	7.2	56.2	<b>5.2</b>	16.3/-2.8/-0.4/-11.5
fiber	3/0/0	153.6	0.1	15.3	0.0	0.0/0.0/-2.6/0.0
fixnet6	3/0/0	<b>57.7</b>	0.1	31.0	1.0	-26.2/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>13.5</b>	0.1	<b>4.5</b>	0.0	-22.2/0.0/-35.6/0.0
germanrr	0/3/0	<b>5.9</b>	<b>17.9</b>	<b>90.3</b>	<b>18.9</b>	-30.5/-34.6/-43.7/-68.8
gesa2	0/3/0	2.4	0.2	20.4	0.0	0.0/0.0/0.0/0.0
gesa2-o	0/3/0	19.4	0.2	35.2	<b>1.3</b>	3.0/0.0/1.1/13.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	2/1/0	<b>796.0</b>	<b>0.4</b>	<b>131.3</b>	<b>45.0</b>	-14.4/-25.0/-20.6/-28.4
gmu-35-40	3/0/0	6.5	0.1	14.0	0.0	0.0/0.0/0.0/0.0
gmu-35-50	3/0/0	<b>8.2</b>	0.3	<b>36.2</b>	<b>1.5</b>	32.8/0.0/-13.3/-33.3
graph20-20-1rand	3/0/0	<b>30.2</b>	<b>4.7</b>	<b>39.9</b>	<b>1.0</b>	-53.6/-12.8/-21.6/-60.0
graphdraw-domain	0/3/0	<b>99.8</b>	<b>0.4</b>	<b>85.0</b>	<b>20.0</b>	-71.1/-25.0/-28.6/-48.0
h80x6320d	3/0/0	22.0	1.2	32.0	1.9	0.0/0.0/0.0/0.0
harp2	3/0/0	12.1	0.1	12.7	0.0	2.4/0.0/0.0/0.0
highschool1-aigio	0/3/0	inf	731.3	<b>24.2</b>	0.0	0.0/-5.8/-36.8/0.0
hypothyroid-k1	3/0/0	0.0	4.6	1.0	0.0	0.0/4.2/0.0/0.0
ic97p	0/0/3	<b>13.3</b>	<b>4.4</b>	767.2	221.3	13.6/13.7/13.5/-7.2
ic97t	0/1/2	<b>14.8</b>	<b>2.7</b>	892.8	258.7	-16.2/30.8/29.5/16.9
icir97p	0/0/3	20.7	21.2	1010.7	145.8	9.6/1.9/11.3/32.4
icir97t	0/3/0	14.4	4.7	216.1	122.6	8.3/-6.4/-2.6/4.8
irish-electricity	3/0/0	5.7	19.9	<b>19.3</b>	<b>0.0</b>	5.0/-2.5/20.2/100.0
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>19.6</b>	6.3	23.0	0.0	45.6/1.6/-4.3/0.0
k1mushroom	3/0/0	18.2	39.8	1.0	0.0	0.0/0.0/0.0/0.0
lectsched-5-obj	0/0/3	2282.3	87.6	908.0	6.4	-1.6/-4.1/0.1/8.6
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	674.7	1.2	90.3	57.3	0.0/-8.3/-0.3/-1.2
lotsize	0/0/3	<b>542.7</b>	<b>7.0</b>	735.6	355.9	-87.0/-92.9/-93.9/-97.0
mad	3/0/0	<b>7880.9</b>	0.1	16.3	0.0	36.2/0.0/-9.8/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>90.6</b>	45.8	<b>59.1</b>	<b>13.2</b>	-50.7/8.2/-39.4/-75.8
map16715-04	3/0/0	90.8	59.4	51.0	10.0	-1.8/-4.2/-9.2/-9.0
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>425.6</b>	0.2	90.0	<b>9.5</b>	10.6/0.0/0.0/34.9
mas76	0/3/0	106.5	0.2	90.0	<b>10.0</b>	-0.7/0.0/0.8/53.5
mc11	3/0/0	105.9	0.4	43.0	12.6	2.1/0.0/-0.9/-2.4
mcsched	3/0/0	<b>9.8</b>	<b>0.6</b>	4.0	0.0	24.0/-16.7/-10.0/0.0
mik-250-20-75-4	0/3/0	<b>53.5</b>	<b>0.1</b>	<b>21.0</b>	<b>2.0</b>	12.4/50.0/45.2/55.6
milo-v12-6-r2-40-1	3/0/0	<b>124.1</b>	0.9	42.3	12.3	17.4/0.0/-0.7/-2.4
misc07	3/0/0	<b>48.9</b>	0.1	<b>17.5</b>	0.0	-41.5/0.0/12.9/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>8.2</b>	0.3	19.6	0.0	41.4/0.0/0.0/0.0
modglob	3/0/0	108.7	0.1	31.3	1.3	-2.6/0.0/0.0/0.0
momentum1	0/1/2	209.2	<b>98.8</b>	1277.7	689.0	-7.6/-60.0/-56.3/-48.8
msc98-ip	3/0/0	<b>11.4</b>	5.7	27.7	0.6	26.5/9.5/9.8/0.0
mushroom-best	0/3/0	<b>1.12e07</b>	14.9	43.3	<b>1.5</b>	-18.1/-8.7/-7.6/11.8
mzzv11	0/3/0	18.2	<b>3.7</b>	20.0	0.0	9.5/11.9/-3.5/0.0

(continued)

Table A.7 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
mzzv42z	0/3/0	<b>37.7</b>	<b>3.9</b>	<b>20.6</b>	<b>0.0</b>	-17.8/20.4/13.4/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	9.5	<b>0.4</b>	<b>27.2</b>	<b>0.3</b>	-1.1/-25.0/-25.0/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>6.4</b>	5.0	29.3	<b>0.4</b>	-85.9/-2.0/-9.9/33.3
neos-1171737	3/0/0	<b>4.5</b>	1.5	<b>25.7</b>	0.6	-13.3/6.3/13.2/0.0
neos-1354092	0/3/0	<b>8.6</b>	160.7	37.2	0.0	52.5/8.8/1.1/0.0
neos-1445765	3/0/0	<b>30.4</b>	<b>0.7</b>	6.1	0.0	14.1/12.5/-8.2/0.0
neos-1456979	0/2/1	<b>86.4</b>	<b>11.8</b>	142.2	17.4	42.4/70.8/69.2/82.0
neos-1582420	0/3/0	<b>90.2</b>	<b>3.6</b>	<b>202.7</b>	<b>24.0</b>	-23.5/-58.3/-60.8/-60.8
neos-2657525-crna	0/3/0	1016.4	<b>0.1</b>	<b>37.2</b>	<b>1.7</b>	0.0/50.0/11.0/15.0
neos-2746589-doon	0/0/3	<b>7.1</b>	<b>932.2</b>	699.0	24.6	79.7/-85.2/-64.5/21.4
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	2/1/0	<b>0.2</b>	<b>10.1</b>	59.0	14.8	33.3/-5.9/-8.0/0.0
neos-3004026-krka	0/0/3	0.0	<b>12.6</b>	1432.2	3.0	0.0/-14.6/-10.2/16.7
neos-3024952-loue	0/0/3	872.7	<b>131.5</b>	1743.9	44.3	-6.8/-39.2/-18.9/-37.2
neos-3046615-murg	0/3/0	10663.7	0.2	100.8	68.9	2.2/0.0/-6.4/-4.8
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	<b>134.8</b>	<b>280.6</b>	1174.1	6.7	-10.3/38.8/-6.6/-100.0
neos-3381206-awhea	0/0/3	4.9	18.9	953.2	0.6	0.0/-3.2/9.6/45.5
neos-3402294-bobin	2/1/0	<b>584.8</b>	19.1	19.4	0.0	-26.6/5.0/-1.5/0.0
neos-3555904-turama	3/0/0	<b>4.3</b>	78.9	<b>35.9</b>	<b>0.6</b>	-53.5/-0.9/-12.5/-33.3
neos-3627168-kasai	3/0/0	1.4	0.1	20.4	0.0	6.7/0.0/0.0/0.0
neos-3656078-kumeu	0/0/3	31.8	<b>125.6</b>	1165.0	2.1	-3.1/10.5/-10.6/-57.1
neos-3754480-nidda	3/0/0	<b>9372.6</b>	0.2	68.6	<b>11.9</b>	-96.1/0.0/-1.3/12.5
neos-4300652-rahue	0/0/3	253.6	<b>773.9</b>	743.8	0.0	4.6/-46.6/-52.3/100.0
neos-4338804-snowy	0/3/0	<b>40074.9</b>	<b>1.0</b>	<b>121.8</b>	<b>32.0</b>	64.8/-20.0/-17.5/-12.5
neos-4387871-tavua	0/0/3	<b>918.1</b>	<b>27.5</b>	1078.4	532.9	-17.8/-16.7/-25.6/-19.8
neos-4413714-turia	3/0/0	<b>32.1</b>	77.8	78.4	<b>10.3</b>	26.9/2.6/1.6/20.8
neos-4532248-waihi	0/0/3	949.4	<b>758.1</b>	940.3	205.2	0.0/-35.5/-53.2/-82.4
neos-4647030-tutaki	3/0/0	<b>33.2</b>	<b>23.7</b>	<b>25.7</b>	0.0	-33.7/-26.2/-31.1/0.0
neos-4722843-widden	0/3/0	<b>53.1</b>	<b>27.5</b>	<b>50.7</b>	<b>6.7</b>	73.1/50.1/45.1/73.8
neos-4738912-atrato	0/3/0	11.4	<b>0.4</b>	<b>21.5</b>	0.0	5.0/-25.0/-42.3/0.0
neos-4763324-toguru	3/0/0	55.6	21.1	23.3	0.0	6.1/0.0/1.7/0.0
neos-4954672-berkel	3/0/0	<b>47.1</b>	0.1	<b>38.0</b>	<b>5.2</b>	13.9/0.0/-15.8/-75.0
neos-5049753-cuanza	0/2/1	<b>60.3</b>	768.7	343.4	91.2	20.2/0.2/-5.2/-21.1
neos-5052403-cygnat	3/0/0	<b>0.6</b>	41.1	2.3	0.0	53.8/2.4/0.0/0.0
neos-5093327-huahum	3/0/0	<b>108.2</b>	<b>8.2</b>	<b>86.0</b>	<b>51.0</b>	88.2/38.8/28.7/41.1
neos-5104907-jarama	0/0/1	120.5	2505.8	811.0	53.0	-/-/-/-
neos-5107597-kakapo	2/1/0	<b>9835.8</b>	<b>3.2</b>	<b>229.9</b>	<b>190.2</b>	75.0/-43.8/-46.4/-50.1
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	4318.9	<b>4.6</b>	24.9	0.0	-7.1/19.3/6.7/0.0
neos-5195221-niemur	3/0/0	<b>918.8</b>	<b>5.5</b>	<b>11.9</b>	0.0	-16.4/25.7/36.4/0.0
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	<b>322.7</b>	<b>4.4</b>	<b>11.3</b>	<b>0.0</b>	-30.9/31.2/41.5/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>4.94e05</b>	105.7	72.7	20.3	-40.1/-2.3/-4.7/1.9
neos-860300	3/0/0	<b>49.1</b>	<b>0.6</b>	<b>6.6</b>	0.0	13.9/-33.3/-39.4/0.0
neos-873061	3/0/0	<b>53.3</b>	26.5	31.7	1.6	12.9/-3.0/0.0/0.0
neos-911970	3/0/0	<b>181.3</b>	0.2	53.0	<b>4.8</b>	-27.2/0.0/-5.7/20.0
neos-933966	3/0/0	<b>196.9</b>	<b>1.4</b>	<b>10.5</b>	0.0	12.1/12.5/-10.5/0.0
neos-950242	2/1/0	<b>80.0</b>	<b>13.7</b>	<b>38.4</b>	<b>2.3</b>	37.6/-51.1/-43.2/-82.6
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	1/2/0	<b>1.7</b>	<b>43.1</b>	<b>171.9</b>	<b>5.1</b>	26.1/-53.1/-64.0/-58.8
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	1.4	<b>7.6</b>	858.2	9.7	0.0/18.3/26.6/-73.2
neos17	3/0/0	306.9	0.2	31.7	1.6	-5.4/0.0/0.0/0.0
neos20	0/0/3	<b>57.0</b>	9.3	1066.5	88.1	-19.8/5.1/9.7/-7.6
neos5	3/0/0	<b>78.7</b>	0.1	<b>3.3</b>	0.0	-47.1/0.0/13.2/0.0

(continued)

Table A.7 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos7	0/3/0	<b>8.8</b>	0.2	27.3	0.0	20.0/0.0/-8.4/0.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>30.5</b>	<b>3.8</b>	<b>22.6</b>	0.0	20.4/11.6/12.1/0.0
netdiversion	3/0/0	84.9	<b>65.5</b>	<b>8.5</b>	0.0	1.7/12.6/11.5/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	<b>8.7</b>	<b>11.3</b>	796.4	214.0	14.7/16.9/27.1/17.4
nh97t	0/0/3	10.6	<b>17.3</b>	1254.5	352.5	0.0/-26.0/-13.0/-7.3
noswot	0/3/0	<b>8.1</b>	0.1	34.2	1.2	15.6/0.0/0.3/7.7
ns1116954	1/0/2	0.0	454.5	493.6	4.1	0.0/3.7/-5.3/-22.0
ns1208400	0/3/0	0.0	88.0	<b>556.0</b>	<b>1.9</b>	0.0/2.3/-28.9/-84.2
ns1644855	3/0/0	<b>0.3</b>	<b>277.8</b>	32.3	<b>1.0</b>	40.0/28.9/6.4/41.2
ns1760995	3/0/0	<b>18.4</b>	77.5	76.0	<b>1.3</b>	-19.0/8.4/5.6/55.2
ns1830653	0/3/0	<b>525.9</b>	<b>14.0</b>	<b>398.1</b>	<b>17.6</b>	-68.8/-68.6/-85.2/-94.3
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ixp	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.3	0.3	19.3	0.0	0.0/0.0/-1.6/0.0
nursesched-medium-hint03	0/3/0	809.8	<b>18.3</b>	<b>20.4</b>	0.0	-2.9/-24.0/-44.1/0.0
nursesched-sprint02	0/3/0	52.1	<b>2.6</b>	<b>13.9</b>	0.0	5.6/-26.9/-33.1/0.0
nw04	3/0/0	3.9	2.1	8.3	0.0	0.0/-4.8/-3.6/0.0
opm2-z10-s4	3/0/0	94.2	27.2	1.0	0.0	0.0/0.4/0.0/0.0
opt1217	3/0/0	<b>4.7</b>	<b>0.2</b>	<b>45.5</b>	<b>6.0</b>	39.7/-50.0/-20.2/-61.7
p200x1188c	3/0/0	3.9	0.2	31.0	1.0	0.0/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/-
pg	3/0/0	<b>10.7</b>	0.3	53.6	<b>16.6</b>	31.0/0.0/-3.5/13.5
pg5-34	3/0/0	<b>5.6</b>	0.4	52.0	<b>11.0</b>	21.1/0.0/0.0/19.1
physiciansched3-3	3/0/0	<b>4.8</b>	49.9	<b>28.5</b>	<b>0.4</b>	44.8/8.4/38.0/60.0
physiciansched6-2	0/0/3	<b>4.4</b>	<b>69.4</b>	818.1	44.4	10.2/17.8/-9.5/-21.6
piperout-08	0/0/3	<b>189.2</b>	<b>50.6</b>	1234.5	43.7	52.1/26.9/27.8/-23.8
piperout-27	0/0/3	<b>50.9</b>	66.9	1209.7	37.6	77.7/-1.3/-1.1/-53.2
pk1	3/0/0	1207.0	0.2	59.0	<b>7.9</b>	-1.3/0.0/-1.7/11.2
pp08a	3/0/0	<b>42.4</b>	0.1	17.3	0.0	27.4/0.0/-9.8/0.0
pp08aCUTS	3/0/0	<b>44.6</b>	0.1	<b>18.7</b>	0.0	-21.3/0.0/-35.8/0.0
proteindesign121hz512p9	0/3/0	2.4	5.1	24.4	0.3	0.0/-2.0/0.0/0.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	3/0/0	66.3	<b>7.2</b>	34.1	<b>0.6</b>	-0.5/14.3/9.8/-100.0
qap10	3/0/0	19.4	13.7	2.0	0.0	0.0/0.0/0.0/0.0
qiu	3/0/0	1563.9	0.1	<b>3.8</b>	0.0	0.0/0.0/-13.2/0.0
rB10-011000	3/0/0	<b>328.6</b>	0.5	<b>22.0</b>	0.0	-26.9/0.0/13.0/0.0
rB10-011001	3/0/0	<b>268.0</b>	0.5	<b>23.5</b>	<b>0.6</b>	-23.8/0.0/10.6/-100.0
rB11-010000	3/0/0	<b>335.4</b>	1.2	<b>24.0</b>	<b>0.3</b>	-13.9/7.7/20.0/50.0
rB11-110001	3/0/0	<b>163.8</b>	<b>3.3</b>	<b>33.7</b>	<b>1.0</b>	21.1/-21.2/-30.9/-70.0
rB12-111111	0/2/1	83.5	<b>56.3</b>	824.1	23.2	7.1/-17.6/-30.3/-86.2
rC10-001000	3/0/0	<b>221.2</b>	<b>0.3</b>	30.2	<b>0.3</b>	19.6/-33.3/-7.6/-100.0
rC10-100001	3/0/0	431.6	4.8	99.8	<b>0.6</b>	-5.4/2.0/1.7/25.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>270.9</b>	<b>7.8</b>	<b>57.3</b>	<b>1.6</b>	15.8/-34.6/-36.5/-50.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>266.1</b>	<b>2.8</b>	<b>116.8</b>	<b>17.6</b>	-42.8/-35.7/-41.5/-79.5
radiationm40-10-02	0/3/0	<b>1128.6</b>	<b>24.6</b>	<b>230.6</b>	<b>18.4</b>	-61.8/-34.1/-37.6/-51.1
rail01	3/0/0	<b>35.4</b>	1192.6	<b>14.9</b>	0.0	-12.4/6.8/-20.1/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<b>25.4</b>	0.3	23.3	<b>0.6</b>	-34.6/0.0/-2.1/-50.0
rd-rplusc-21	0/0/3	56.0	39.3	882.7	362.6	3.6/-7.9/-1.8/-0.6
reblock115	3/0/0	<b>9.2</b>	<b>1.8</b>	<b>67.0</b>	<b>9.8</b>	17.9/-11.1/-17.3/-36.7
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.1	2.0	0.0	0.0/0.0/0.0/0.0
rocl-4-11	0/0/3	<b>51.7</b>	<b>18.5</b>	817.9	91.5	25.3/12.7/12.3/11.8
rocll-5-11	0/3/0	<b>68.1</b>	<b>23.9</b>	<b>464.8</b>	<b>153.2</b>	24.7/-64.9/-66.4/-65.7

(continued)

Table A.7 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
roi2alpha3n4	3/0/0	<b>36.7</b>	<b>38.0</b>	37.2	<b>2.2</b>	41.2/-12.4/-7.8/-27.3
roi5alpha10n8	3/0/0	56.8	472.5	31.8	<b>0.6</b>	5.5/-5.5/-8.8/-100.0
roll3000	0/3/0	27.4	1.1	52.5	<b>6.3</b>	-4.4/0.0/-7.8/-28.6
rout	0/3/0	<b>42.1</b>	0.2	<b>46.7</b>	<b>6.1</b>	14.9/0.0/-24.6/-72.1
s100	3/0/0	<b>2.8</b>	298.7	7.0	0.0	-39.3/1.3/-5.7/0.0
s250r10	3/0/0	0.1	53.3	2.0	0.0	0.0/0.2/0.0/0.0
satellites2-40	0/3/0	<b>287.5</b>	<b>71.8</b>	<b>147.0</b>	<b>57.0</b>	-14.6/-38.4/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>95.1</b>	410.2	182.9	-60.0/-76.2/-91.5/-98.5
savsched1	0/3/0	<b>7.0</b>	199.1	13.0	0.0	11.4/-4.5/-5.4/0.0
sct2	3/0/0	<b>23.2</b>	0.6	26.9	<b>0.0</b>	20.5/0.0/-3.0/100.0
set1ch	3/0/0	<b>61.9</b>	0.1	31.0	1.0	27.7/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	1.4	<b>3.1</b>	<b>8.6</b>	0.0	0.0/-12.9/-11.6/0.0
sing326	3/0/0	<b>9.3</b>	<b>27.9</b>	37.3	<b>2.9</b>	12.3/-11.5/-8.8/-44.8
sing44	3/0/0	7.3	26.1	37.6	<b>2.7</b>	1.4/1.1/2.3/28.9
snp-02-004-104	0/3/0	1.7	19.8	33.6	1.9	0.0/-0.5/0.0/0.0
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.3	1.3	0.0/0.0/0.0/0.0
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	100.2	61.7	13.0	0.0	-1.6/0.6/0.0/0.0
square41	0/3/0	6.7	<b>1535.4</b>	<b>12.4</b>	0.0	0.0/-20.5/-19.4/0.0
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>153.2</b>	108.0	<b>11.6</b>	0.0	10.0/1.9/14.7/0.0
supportcase12	0/3/0	<b>2.1</b>	13.6	21.6	0.0	-14.3/6.8/-2.8/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>5459.8</b>	0.2	90.0	59.7	41.8/0.0/-0.3/5.7
supportcase33	0/3/0	<b>57.1</b>	<b>19.6</b>	<b>194.9</b>	<b>43.2</b>	11.5/-29.6/-37.8/-66.4
supportcase40	3/0/0	<b>24.3</b>	4.5	<b>18.5</b>	0.0	-27.6/-6.7/-10.3/0.0
supportcase42	0/3/0	<b>14.3</b>	<b>4.9</b>	<b>13.7</b>	0.0	41.4/-14.3/-15.3/0.0
supportcase6	3/0/0	<b>2.6</b>	13.1	12.7	0.0	-84.6/1.5/-5.5/0.0
supportcase7	3/0/0	15.1	8.7	26.0	0.0	-5.3/-4.6/0.0/0.0
swath	0/3/0	192.9	<b>21.5</b>	<b>274.2</b>	<b>92.4</b>	-5.9/-37.2/-31.5/-35.5
swath1	3/0/0	<b>18.1</b>	<b>1.1</b>	<b>41.3</b>	<b>4.4</b>	70.0/52.2/33.6/72.0
swath3	3/0/0	<b>19.2</b>	<b>1.2</b>	42.4	<b>5.4</b>	42.2/20.0/1.2/-40.7
t1717	3/0/0	179.1	<b>148.6</b>	<b>63.2</b>	0.0	0.1/-15.0/-31.2/0.0
tbfp-network	3/0/0	<b>173.7</b>	<b>25.4</b>	14.8	0.0	12.9/-11.8/-5.4/0.0
thor50dday	3/0/0	257.8	7.2	24.5	1.7	0.0/0.0/0.0/0.0
timtab1	0/3/0	57.9	<b>0.4</b>	<b>71.8</b>	<b>20.7</b>	-4.1/33.3/36.9/25.8
timtab2	0/2/1	73.6	<b>5.2</b>	511.7	181.6	0.0/10.3/35.3/32.9
tr12-30	3/0/0	69.2	0.2	31.3	<b>1.3</b>	5.1/0.0/1.3/18.8
traininstance2	0/1/2	254.2	<b>5.1</b>	940.4	108.6	-4.2/-35.3/-30.9/-36.8
traininstance6	0/3/0	<b>115.1</b>	<b>0.4</b>	132.7	15.2	75.1/66.7/56.6/63.9
trento1	3/0/0	<b>283.3</b>	8.2	<b>10.9</b>	0.0	-34.0/-2.4/-14.7/0.0
triptim1	0/3/0	0.1	22.7	4.2	0.0	0.0/2.6/-4.8/0.0
uccase12	3/0/0	<b>2.7</b>	10.7	16.2	0.0	-29.6/-3.7/-3.7/0.0
uccase9	3/0/0	<b>4856.6</b>	<b>33.4</b>	103.0	40.4	13.4/42.3/45.7/44.7
uct-subprob	3/0/0	<b>15.4</b>	<b>0.5</b>	<b>9.7</b>	0.0	-19.5/16.7/-20.6/0.0
unitcal-7	0/1/2	<b>39.7</b>	134.5	1008.4	186.5	-32.5/2.3/-1.7/-21.8
var-smallemary-m6j6	3/0/0	<b>45.8</b>	24.0	68.3	9.6	82.1/0.0/-1.2/5.0
vp2	3/0/0	43.8	0.1	<b>27.2</b>	<b>0.3</b>	2.7/0.0/-25.0/-100.0
wachplan	0/3/0	0.0	<b>2.6</b>	24.5	0.0	0.0/13.3/7.5/0.0
Geom. means		(271 instances)		(231 instances)		
FP		45.7	5.4	16.2	1.2	
FP+(2,l,g)		<b>45.3</b>	<b>5.6</b>	<b>17.4</b>	<b>1.3</b>	

Table A.8.: Performance of FP+(3,1,g)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	2/1/0	<b>5.2</b>	<b>4.3</b>	<b>77.7</b>	<b>1.5</b>	57.0/64.8/51.3/-20.0
30n20b8	0/2/1	<b>1389.6</b>	<b>14.4</b>	514.9	130.1	-66.7/-60.4/-67.6/-77.8
50v-10	0/3/0	137.9	0.3	22.0	0.3	-9.6/0.0/4.3/0.0
CMS750-4	3/0/0	<b>64.3</b>	<b>6.3</b>	<b>104.7</b>	11.6	-17.6/-34.9/-37.8/3.3
a1c1s1	3/0/0	<b>66.3</b>	<b>0.5</b>	31.7	<b>1.6</b>	-20.4/-20.0/-1.3/-18.8
academictimetables	0/0/3	inf	663.5	1089.7	0.3	-/-/-/-
aflow30a	3/0/0	119.0	0.1	32.0	<b>1.5</b>	9.6/0.0/4.5/25.0
aflow40b	3/0/0	196.5	0.3	34.3	<b>2.9</b>	5.2/0.0/-6.7/-48.3
air04	3/0/0	<b>0.5</b>	2.7	7.1	0.0	-80.0/-3.7/-7.0/0.0
air05	3/0/0	<b>3.1</b>	<b>1.7</b>	<b>16.1</b>	0.0	24.4/-52.9/-75.2/0.0
app1-1	3/0/0	<b>33.3</b>	<b>0.6</b>	<b>39.4</b>	<b>5.9</b>	-90.7/-16.7/-12.2/-32.2
app1-2	1/2/0	43.9	<b>17.9</b>	<b>91.5</b>	<b>36.1</b>	0.0/-40.2/-43.4/-57.6
arki001	0/0/3	2.9	<b>29.1</b>	1072.0	263.6	0.0/-28.9/-25.0/-29.3
assign1-5-8	3/0/0	<b>0.6</b>	0.1	21.3	0.0	68.4/0.0/4.5/0.0
atlanta-ip	3/0/0	<b>9.3</b>	15.5	<b>19.6</b>	<b>0.0</b>	48.3/8.3/24.0/100.0
b1c1s1	3/0/0	<b>218.0</b>	0.5	34.0	4.0	-26.0/0.0/-0.9/-10.0
bab2	2/0/1	<b>10.2</b>	<b>260.5</b>	146.0	8.3	60.0/17.1/15.6/64.7
bab6	1/0/2	<b>12.1</b>	<b>268.5</b>	296.6	49.8	48.9/-61.1/-70.4/-69.3
beasleyC3	3/0/0	11.4	0.2	36.0	<b>6.0</b>	1.7/0.0/-2.8/-20.0
binkar10-1	3/0/0	3.9	0.1	<b>7.7</b>	0.0	2.5/0.0/51.0/0.0
blp-ar98	3/0/0	72.7	2.1	17.9	0.0	-1.9/-4.8/-5.6/0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/3	0.0	<b>257.5</b>	1025.8	0.0	0.0/-17.4/-17.4/0.0
bppc4-08	3/0/0	<b>38.7</b>	1.1	60.6	9.5	25.0/8.3/2.7/-2.1
brazil3	0/3/0	<b>523.4</b>	19.5	<b>25.6</b>	0.0	17.5/7.6/-16.4/0.0
buildingenergy	0/3/0	1.1	<b>626.8</b>	11.0	0.0	0.0/10.0/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.7	40.3	10.3	0.0/0.0/-0.7/-2.9
chromaticindex1024-7	3/0/0	0.0	54.0	<b>2.3</b>	0.0	0.0/1.5/23.3/0.0
chromaticindex512-7	3/0/0	0.0	44.8	2.0	0.0	0.0/0.4/0.0/0.0
cmflsp50-24-8-8	1/0/2	19.2	<b>79.7</b>	582.8	184.5	1.5/52.4/44.5/37.4
co-100	3/0/0	<b>377.2</b>	<b>5.4</b>	14.3	0.0	-19.7/11.5/8.3/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	<b>3907.3</b>	6.2	25.3	0.0	-12.3/0.0/-5.1/0.0
comp21-2idx	0/3/0	442.6	4.4	25.6	0.0	-3.5/4.3/-2.0/0.0
cost266-UUE	3/0/0	<b>29.4</b>	<b>0.5</b>	<b>32.3</b>	<b>1.3</b>	16.2/-20.0/-27.2/-76.9
cryptanalysisk128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/0/3	<b>50.9</b>	<b>12.9</b>	1305.3	306.5	26.2/-52.7/-70.7/-83.9
csched008	1/2/0	9.2	<b>2.4</b>	<b>275.4</b>	<b>70.9</b>	6.1/-29.2/-44.8/-66.1
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	18.5	16.6	0.0	0.0/1.1/-2.4/0.0
dano3-5	3/0/0	<b>0.1</b>	<b>34.1</b>	31.5	<b>1.1</b>	50.0/22.5/-4.4/-18.2
dano3mip	3/0/0	<b>10.0</b>	<b>152.8</b>	70.0	17.3	41.9/45.5/0.8/5.5
danoint	3/0/0	<b>14.7</b>	<b>2.1</b>	<b>72.1</b>	<b>20.1</b>	97.7/47.5/35.3/51.2
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	5.7	<b>0.4</b>	<b>15.0</b>	0.0	-1.8/-25.0/-13.3/0.0
drayage-25-23	3/0/0	<b>6.5</b>	<b>0.6</b>	<b>20.3</b>	0.0	36.3/-33.3/-19.2/0.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0
dws008-01	0/0/3	<b>52.1</b>	<b>56.6</b>	729.0	215.4	45.7/24.1/11.1/8.6
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0	0.0/0.0/0.0/0.0
enlight-hard	0/0/1	0.0	2.5	723.0	226.0	-/-/-/-
exp-1-500-5-5	3/0/0	<b>136.7</b>	0.1	27.9	<b>0.3</b>	-44.8/0.0/-3.6/-100.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>738.5</b>	0.4	<b>26.5</b>	<b>0.8</b>	18.6/0.0/-23.4/-100.0
fhnw-binpack4-48	0/0/2	0.0	74.7	1798.8	226.3	-/-/-/-
fiball	0/3/0	15.9	6.6	52.3	4.6	7.6/5.7/6.6/0.0
fiber	3/0/0	153.6	0.1	15.7	0.0	0.0/0.0/-5.1/0.0
fixnet6	3/0/0	<b>53.9</b>	0.1	31.0	1.0	-21.0/0.0/0.0/0.0

(continued)

Table A.8 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>13.5</b>	0.1	<b>4.5</b>	0.0	-22.2/0.0/-35.6/0.0
germanrr	0/3/0	<b>2.8</b>	10.7	48.5	5.8	31.7/8.5/4.5/1.7
gesa2	0/3/0	2.4	0.2	20.4	0.0	0.0/0.0/0.0/0.0
gesa2-o	0/3/0	<b>15.9</b>	0.2	34.6	1.6	20.5/0.0/2.8/-6.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	2/1/0	<b>1202.5</b>	<b>0.4</b>	<b>148.2</b>	<b>63.2</b>	-43.3/-25.0/-29.7/-49.1
gmu-35-40	3/0/0	6.5	0.1	14.0	0.0	0.0/0.0/0.0/0.0
gmu-35-50	3/0/0	<b>10.9</b>	<b>0.5</b>	<b>47.3</b>	<b>4.1</b>	10.7/-40.0/-33.6/-75.6
graph20-20-1rand	3/0/0	<b>22.2</b>	4.2	<b>42.6</b>	<b>0.8</b>	-36.9/-2.4/-26.5/-50.0
graphdraw-domain	0/3/0	<b>144.1</b>	<b>0.5</b>	<b>97.5</b>	<b>25.2</b>	-80.0/-40.0/-37.7/-58.7
h80x6320d	3/0/0	21.0	1.2	32.0	1.9	4.5/0.0/0.0/0.0
harp2	3/0/0	11.5	0.1	13.3	0.0	7.3/0.0/-4.5/0.0
highschool1-aigio	0/3/0	inf	<b>790.8</b>	<b>24.8</b>	0.0	0.0/-12.9/-38.3/0.0
hypothyroid-k1	3/0/0	0.0	4.6	1.0	0.0	0.0/4.2/0.0/0.0
ic97p	0/0/3	14.7	<b>5.8</b>	914.6	267.6	4.5/-12.1/-3.0/-23.2
ic97t	0/0/3	<b>14.3</b>	3.7	1177.5	338.3	-13.3/5.1/7.0/-8.0
icir97p	0/0/3	<b>20.1</b>	<b>18.6</b>	816.8	184.1	12.2/13.9/28.3/14.6
icir97t	0/3/0	14.7	<b>7.4</b>	<b>268.8</b>	<b>159.0</b>	6.4/-40.5/-21.7/-19.0
irish-electricity	3/0/0	5.8	<b>21.6</b>	<b>21.3</b>	<b>0.0</b>	3.3/-10.2/12.0/100.0
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>19.0</b>	6.6	22.6	0.0	47.2/-3.0/-2.7/0.0
k1mushroom	3/0/0	18.2	40.0	1.0	0.0	0.0/-0.5/0.0/0.0
lectsched-5-obj	0/0/3	<b>2717.0</b>	<b>107.3</b>	1135.2	6.1	-17.4/-21.7/-20.0/12.9
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>515.6</b>	1.2	89.7	56.6	23.6/-8.3/0.3/0.0
lotsize	3/0/0	<b>87.1</b>	<b>0.6</b>	<b>52.7</b>	<b>14.0</b>	-18.8/-16.7/-14.8/-25.0
mad	3/0/0	<b>8228.9</b>	<b>0.2</b>	<b>17.0</b>	0.0	33.4/-50.0/-13.5/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>27.3</b>	47.1	<b>55.5</b>	<b>12.4</b>	38.9/5.6/-35.5/-74.2
map16715-04	3/0/0	82.6	59.2	<b>54.1</b>	<b>11.4</b>	7.4/-3.9/-14.4/-20.2
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>1233.3</b>	0.2	90.0	<b>9.6</b>	-61.4/0.0/0.0/34.2
mas76	0/3/0	<b>293.3</b>	0.2	90.0	<b>10.3</b>	-63.9/0.0/0.8/52.1
mc11	3/0/0	100.3	0.4	42.6	12.3	7.3/0.0/0.0/0.0
mcsched	3/0/0	<b>15.6</b>	0.5	4.0	0.0	-17.3/0.0/-10.0/0.0
mik-250-20-75-4	0/3/0	<b>52.4</b>	0.2	<b>21.0</b>	<b>2.0</b>	14.2/0.0/45.2/55.6
milo-v12-6-r2-40-1	3/0/0	<b>126.0</b>	0.9	43.0	12.9	16.2/0.0/-2.3/-7.0
misc07	3/0/0	<b>39.5</b>	<b>0.2</b>	<b>23.7</b>	<b>0.6</b>	-27.6/-50.0/-15.2/-100.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>6.5</b>	0.3	19.6	0.0	53.6/0.0/0.0/0.0
modglob	3/0/0	<b>123.1</b>	0.1	31.3	1.3	-14.0/0.0/0.0/0.0
momentum1	0/0/2	165.3	54.6	809.9	406.1	-/-/-/-
msc98-ip	3/0/0	<b>12.3</b>	6.2	32.0	<b>1.0</b>	20.6/1.6/-4.1/-40.0
mushroom-best	0/3/0	<b>1.91e06</b>	<b>12.0</b>	36.3	<b>1.5</b>	79.2/11.8/9.3/11.8
mzzv11	0/3/0	<b>17.6</b>	<b>3.7</b>	20.3	0.0	12.4/11.9/-4.9/0.0
mzzv42z	0/3/0	<b>20.8</b>	<b>4.0</b>	<b>21.3</b>	<b>0.0</b>	32.9/18.4/10.5/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>5.7</b>	<b>0.4</b>	<b>27.2</b>	<b>0.3</b>	39.4/-25.0/-25.0/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>19.1</b>	5.0	<b>29.5</b>	<b>0.8</b>	-95.3/-2.0/-10.5/-25.0
neos-1171737	3/0/0	<b>4.9</b>	<b>1.8</b>	<b>33.0</b>	<b>2.0</b>	-20.4/-11.1/-10.3/-70.0
neos-1354092	0/3/0	<b>11.0</b>	169.6	<b>42.3</b>	<b>0.3</b>	39.2/3.8/-11.1/-100.0
neos-1445765	3/0/0	<b>29.6</b>	<b>0.7</b>	5.8	0.0	16.4/12.5/-3.4/0.0
neos-1456979	0/0/3	<b>122.1</b>	<b>87.1</b>	1167.3	121.7	18.5/-53.6/-60.4/-20.7
neos-1582420	0/3/0	<b>99.8</b>	<b>4.6</b>	<b>299.8</b>	<b>56.2</b>	-30.9/-67.4/-73.5/-83.3

(continued)



Table A.8 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-2657525-crna	0/3/0	960.7	<b>0.1</b>	<b>27.2</b>	<b>1.5</b>	5.5/50.0/34.9/25.0
neos-2746589-doon	0/0/3	<b>9.3</b>	<b>899.2</b>	715.0	27.6	73.4/-84.6/-65.3/11.8
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	2/1/0	0.3	<b>10.9</b>	<b>64.1</b>	<b>17.3</b>	0.0/-12.8/-15.3/-14.5
neos-3004026-krka	0/0/3	0.0	114.4	1276.6	4.2	0.0/-4.7/0.7/-14.3
neos-3024952-loue	0/2/1	<b>937.9</b>	<b>136.1</b>	1364.0	23.8	-13.3/-41.3/3.5/14.4
neos-3046615-murg	0/3/0	<b>158.6</b>	0.2	96.3	64.8	98.5/0.0/-2.1/1.2
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	130.9	<b>174.0</b>	1013.3	63.3	-7.6/62.0/7.6/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>24.9</b>	1114.2	0.0	0.0/-26.5/-5.4/100.0
neos-3402294-bobin	2/1/0	<b>508.2</b>	<b>23.4</b>	<b>26.8</b>	<b>1.2</b>	-15.5/-14.1/-28.7/-100.0
neos-3555904-turama	3/0/0	<b>4.3</b>	<b>69.5</b>	<b>26.4</b>	<b>0.0</b>	-53.5/11.1/15.9/100.0
neos-3627168-kasai	3/0/0	<b>1.7</b>	<b>0.2</b>	<b>27.8</b>	<b>0.4</b>	-11.8/-50.0/-26.6/-100.0
neos-3656078-kumeu	0/0/3	28.5	130.6	1088.4	0.4	7.5/6.9/-4.3/55.6
neos-3754480-nidda	3/0/0	<b>17.2</b>	0.2	67.7	<b>11.0</b>	95.3/0.0/0.0/19.1
neos-4300652-rahue	0/1/2	<b>211.0</b>	<b>329.7</b>	368.2	1.9	20.6/20.2/-3.7/-84.2
neos-4338804-snowy	0/3/0	<b>19977.4</b>	<b>1.0</b>	<b>122.2</b>	<b>33.1</b>	82.5/-20.0/-17.8/-15.4
neos-4387871-tavua	0/0/3	<b>844.4</b>	23.7	974.2	533.3	-10.6/-3.4/-17.7/-19.9
neos-4413714-turia	3/0/0	<b>5.6</b>	72.3	<b>71.5</b>	12.3	87.2/9.5/10.3/5.4
neos-4532248-waihi	0/0/3	949.4	<b>659.5</b>	817.0	280.6	0.0/-25.9/-46.2/-87.1
neos-4647030-tutaki	3/0/0	<b>13.8</b>	<b>24.4</b>	<b>26.0</b>	0.0	37.3/-28.3/-31.9/0.0
neos-4722843-widden	0/3/0	<b>47.2</b>	<b>34.8</b>	<b>61.7</b>	<b>11.1</b>	76.1/36.8/33.2/56.6
neos-4738912-atrato	0/3/0	<b>8.0</b>	<b>0.4</b>	<b>21.5</b>	0.0	33.3/-25.0/-42.3/0.0
neos-4763324-toguru	3/0/0	55.6	20.9	23.3	0.0	6.1/0.9/1.7/0.0
neos-4954672-berkel	3/0/0	<b>31.1</b>	0.1	<b>36.3</b>	<b>3.8</b>	43.1/0.0/-11.8/-65.8
neos-5049753-cuanza	1/0/2	<b>45.6</b>	<b>1200.6</b>	520.3	158.9	39.7/-35.8/-37.4/-54.7
neos-5052403-cygnnet	3/0/0	<b>0.6</b>	41.2	2.3	0.0	53.8/2.1/0.0/0.0
neos-5093327-huahum	3/0/0	<b>90.1</b>	<b>8.1</b>	<b>84.7</b>	<b>50.3</b>	90.1/39.6/29.8/41.9
neos-5104907-jarama	0/0/2	146.5	2240.4	888.7	131.3	-/-/-/-
neos-5107597-kakapo	3/0/0	43086.0	<b>2.4</b>	<b>173.6</b>	<b>139.5</b>	-8.8/-25.0/-29.0/-32.0
neos-5114902-kasavu	0/1/0	44.9	2529.9	129.0	28.0	-/-/-/-
neos-5188808-nattai	3/0/0	4230.3	<b>4.7</b>	24.5	0.0	-5.1/17.5/8.2/0.0
neos-5195221-niemur	3/0/0	<b>687.9</b>	<b>6.0</b>	<b>14.7</b>	0.0	10.4/18.9/21.4/0.0
neos-631710	3/0/0	149.4	2.3	1.0	0.0	0.0/8.0/0.0/0.0
neos-662469	0/3/0	<b>293.8</b>	<b>4.3</b>	<b>12.2</b>	<b>0.0</b>	-24.1/32.8/36.8/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>5.00e05</b>	107.4	74.7	21.0	-40.8/-3.8/-7.2/-1.4
neos-860300	3/0/0	<b>64.9</b>	<b>0.5</b>	<b>6.0</b>	0.0	-12.2/-20.0/-33.3/0.0
neos-873061	3/0/0	55.2	27.6	32.0	<b>2.0</b>	9.8/-6.9/-0.9/-20.0
neos-911970	3/0/0	<b>173.1</b>	0.2	<b>56.0</b>	<b>3.3</b>	-23.7/0.0/-10.7/45.0
neos-933966	3/0/0	<b>197.6</b>	1.5	<b>10.5</b>	0.0	11.8/6.3/-10.5/0.0
neos-950242	2/1/0	<b>92.2</b>	<b>10.8</b>	<b>34.2</b>	<b>1.5</b>	28.1/-38.0/-36.3/-73.3
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	0/2/1	<b>9.7</b>	<b>140.6</b>	606.3	36.8	-76.3/-85.6/-89.8/-94.3
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	1.5	<b>7.6</b>	845.0	4.2	-6.7/18.3/27.7/-38.1
neos17	3/0/0	306.3	0.2	32.0	1.6	-5.3/0.0/-0.9/0.0
neos20	0/0/3	<b>56.9</b>	10.1	1174.6	82.2	-19.7/-3.0/0.6/-1.0
neos5	3/0/0	<b>74.8</b>	0.1	<b>3.3</b>	0.0	-44.4/0.0/13.2/0.0
neos7	0/3/0	<b>13.7</b>	<b>0.3</b>	<b>31.7</b>	<b>0.9</b>	-19.7/-33.3/-21.1/-100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>19.2</b>	<b>3.6</b>	<b>21.3</b>	0.0	49.9/16.3/17.1/0.0
netdiversion	3/0/0	82.9	<b>62.4</b>	<b>7.3</b>	0.0	4.1/16.7/24.0/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	9.5	<b>11.1</b>	686.7	128.7	6.9/18.4/37.1/50.3
nh97t	0/0/3	10.8	<b>21.9</b>	1204.5	304.8	-1.9/-41.6/-9.4/6.7
noswot	0/3/0	<b>6.2</b>	0.1	33.0	<b>0.6</b>	35.4/0.0/3.8/53.8
ns1116954	0/0/3	0.0	<b>849.6</b>	980.7	2.0	0.0/-44.5/-52.4/37.5
ns1208400	0/2/1	0.0	<b>69.2</b>	395.3	1.5	0.0/23.2/0.1/-80.0
ns1644855	3/0/0	<b>1.9</b>	<b>509.0</b>	<b>45.6</b>	<b>5.6</b>	-73.7/-23.3/-24.3/-69.6

(continued)

Table A.8 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
ns1760995	3/0/0	13.9	<b>75.8</b>	75.7	<b>1.6</b>	6.7/10.4/6.0/44.8
ns1830653	2/1/0	162.0	<b>3.8</b>	<b>93.2</b>	<b>9.3</b>	1.3/13.6/-36.9/-89.2
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ipx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.2	0.3	19.0	0.0	3.0/0.0/0.0/0.0
nursesched-medium-hint03	0/3/0	787.2	<b>19.2</b>	<b>22.4</b>	0.0	-0.1/-27.6/-49.1/0.0
nursesched-sprint02	0/3/0	55.2	<b>2.7</b>	<b>15.0</b>	0.0	0.0/-29.6/-38.0/0.0
nw04	3/0/0	3.9	<b>2.3</b>	<b>9.3</b>	0.0	0.0/-13.0/-14.0/0.0
opm2-z10-s4	3/0/0	94.2	27.3	1.0	0.0	0.0/0.0/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	<b>0.2</b>	<b>47.0</b>	<b>5.5</b>	100.0/-50.0/-22.8/-58.2
p200x1188c	3/0/0	<b>4.4</b>	0.2	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/1	0.0	272.8	1041.0	113.0	-/-/-/-
pg	3/0/0	<b>5.0</b>	0.3	54.8	17.6	67.7/0.0/-5.7/8.3
pg5-34	3/0/0	<b>5.0</b>	0.4	52.7	<b>12.0</b>	29.6/0.0/-1.3/11.8
physiciansched3-3	3/0/0	<b>101.7</b>	<b>65.8</b>	<b>97.5</b>	<b>5.5</b>	-91.4/-17.2/-52.8/-81.8
physiciansched6-2	0/1/2	<b>3.1</b>	<b>57.9</b>	774.8	68.2	36.7/31.4/-4.5/-49.0
piperout-08	0/0/3	<b>224.3</b>	<b>79.6</b>	1892.4	47.6	43.2/-13.1/-9.6/-30.0
piperout-27	0/0/3	<b>72.4</b>	<b>58.1</b>	1069.0	27.7	68.3/12.0/10.7/-36.5
pk1	3/0/0	<b>850.7</b>	0.2	59.7	<b>8.0</b>	28.6/0.0/-2.8/10.1
pp08a	3/0/0	<b>24.5</b>	0.1	<b>19.3</b>	0.0	58.0/0.0/-19.2/0.0
pp08aCUTS	3/0/0	<b>40.8</b>	0.1	<b>17.2</b>	0.0	-14.0/0.0/-30.2/0.0
proteindesign121hz512p9	0/3/0	2.4	5.1	24.4	0.3	0.0/-2.0/0.0/0.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	2/1/0	65.7	9.1	<b>58.4</b>	<b>0.8</b>	0.5/-7.7/-35.3/-100.0
qap10	3/0/0	19.4	13.7	2.0	0.0	0.0/0.0/0.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	<b>307.5</b>	0.5	<b>21.9</b>	<b>0.3</b>	-21.9/0.0/13.4/-100.0
rB10-011001	3/0/0	226.5	0.5	24.8	<b>0.3</b>	-9.9/0.0/5.7/-100.0
rB11-010000	3/0/0	264.0	<b>1.6</b>	<b>35.2</b>	<b>0.8</b>	8.6/-18.8/-14.8/-25.0
rB11-110001	3/0/0	219.8	2.8	<b>26.0</b>	0.3	-5.6/-7.1/-10.4/0.0
rB12-111111	1/2/0	<b>75.8</b>	<b>27.5</b>	376.3	15.8	15.7/40.7/34.5/-79.7
rC10-001000	3/0/0	<b>160.0</b>	<b>0.3</b>	29.9	0.0	41.8/-33.3/-6.7/0.0
rC10-100001	3/0/0	412.3	<b>4.4</b>	91.6	<b>1.9</b>	-0.9/10.2/9.8/-57.9
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>225.8</b>	<b>9.7</b>	<b>71.6</b>	<b>1.9</b>	29.8/-47.4/-49.2/-57.9
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>178.0</b>	<b>3.3</b>	<b>113.2</b>	<b>14.7</b>	-14.6/-45.5/-39.7/-75.5
radiationm40-10-02	0/3/0	<b>7492.5</b>	<b>30.9</b>	<b>293.2</b>	<b>34.2</b>	-94.2/-47.6/-51.0/-73.7
rail01	3/0/0	32.6	<b>1104.4</b>	<b>14.0</b>	0.0	-4.9/13.7/-15.0/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.1	1.0	0.0	0.0/8.3/0.0/0.0
ran14x18-disj-8	3/0/0	<b>24.8</b>	0.3	<b>20.4</b>	<b>0.0</b>	-33.1/0.0/10.5/100.0
rd-rplusc-21	0/0/3	57.3	35.0	897.7	390.9	1.4/3.3/-3.5/-7.8
reblock115	3/0/0	<b>9.7</b>	<b>1.9</b>	<b>69.5</b>	<b>7.1</b>	13.4/-15.8/-20.3/-12.7
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.1	2.0	0.0	0.0/0.0/0.0/0.0
rocl-4-11	0/0/3	<b>41.7</b>	<b>17.8</b>	795.8	96.6	39.7/16.0/14.6/6.9
rocll-5-11	0/1/2	90.8	<b>55.4</b>	1084.8	422.3	-0.4/-84.8/-85.6/-87.5
roi2alpha3n4	3/0/0	<b>38.1</b>	35.6	37.3	1.7	38.9/-6.5/-8.0/-5.9
roi5alpha10n8	3/0/0	55.2	471.7	30.9	<b>0.4</b>	8.2/-5.3/-6.1/-100.0
roll3000	0/3/0	28.3	1.2	<b>61.6</b>	<b>8.3</b>	-7.4/-8.3/-21.4/-45.8
rout	0/3/0	50.1	0.2	<b>40.9</b>	<b>3.1</b>	-1.2/0.0/-13.9/-45.2
s100	3/0/0	<b>2.8</b>	<b>251.2</b>	<b>4.0</b>	0.0	-39.3/17.0/39.4/0.0
s250r10	3/0/0	0.1	53.3	2.0	0.0	0.0/0.2/0.0/0.0
satellites2-40	0/3/0	<b>310.9</b>	<b>72.8</b>	<b>147.0</b>	<b>57.0</b>	-21.1/-39.3/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>93.7</b>	410.0	182.7	-60.0/-75.9/-91.5/-98.5
savsched1	0/3/0	8.0	197.8	13.0	0.0	-1.2/-3.9/-5.4/0.0
sct2	3/0/0	27.6	<b>0.7</b>	<b>30.9</b>	0.6	5.5/-14.3/-15.5/0.0
set1ch	3/0/0	<b>58.3</b>	0.1	31.0	1.0	31.9/0.0/0.0/0.0

(continued)

Table A.8 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<b>8.6</b>	<b>3.1</b>	<b>8.6</b>	0.0	-83.7/-12.9/-11.6/0.0
sing326	3/0/0	11.7	<b>29.6</b>	<b>39.9</b>	<b>3.8</b>	-9.4/-16.6/-14.8/-57.9
sing44	3/0/0	7.9	27.6	40.6	3.9	-6.3/-4.3/-5.2/-2.6
snp-02-004-104	0/3/0	1.7	20.1	33.6	1.9	0.0/-2.0/0.0/0.0
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.7	<b>1.6</b>	0.0/0.0/-1.3/-18.8
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	98.8	63.1	13.2	0.0	-0.2/-1.6/-1.5/0.0
square41	0/3/0	6.7	1285.2	10.0	0.0	0.0/-5.0/0.0/0.0
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>123.7</b>	105.8	<b>11.7</b>	0.0	27.4/3.9/14.0/0.0
supportcase12	0/3/0	<b>2.2</b>	16.2	<b>23.9</b>	0.0	-18.2/-9.9/-12.1/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>4414.0</b>	0.2	90.0	59.7	53.0/0.0/-0.3/5.7
supportcase33	0/3/0	<b>81.8</b>	13.6	<b>148.5</b>	15.7	-21.1/1.4/-18.3/-7.6
supportcase40	3/0/0	17.1	4.5	17.8	0.0	2.8/-6.7/-6.7/0.0
supportcase42	0/3/0	<b>14.3</b>	<b>5.0</b>	<b>14.1</b>	0.0	41.4/-16.0/-17.7/0.0
supportcase6	3/0/0	0.4	<b>15.2</b>	<b>15.8</b>	0.0	0.0/-12.5/-24.1/0.0
supportcase7	3/0/0	<b>12.6</b>	8.9	26.0	0.0	11.9/-6.7/0.0/0.0
swath	0/2/1	186.2	<b>32.1</b>	398.3	143.0	-2.5/-57.9/-52.8/-58.3
swath1	3/0/0	<b>25.9</b>	<b>1.0</b>	<b>39.0</b>	<b>4.0</b>	57.1/56.5/37.3/74.5
swath3	3/0/0	<b>24.4</b>	<b>1.2</b>	43.7	<b>5.7</b>	26.5/20.0/-1.8/-43.9
t1717	3/0/0	<b>152.5</b>	<b>110.5</b>	45.6	0.0	14.9/12.5/-4.6/0.0
tbf-network	3/0/0	<b>47.9</b>	<b>16.5</b>	<b>15.7</b>	0.0	76.0/26.3/-10.8/0.0
thor50dday	3/0/0	257.8	7.3	24.5	1.7	0.0/-1.4/0.0/0.0
timtab1	0/3/0	53.5	<b>0.3</b>	<b>61.9</b>	<b>14.7</b>	3.6/50.0/45.6/47.3
timtab2	0/1/2	<b>84.9</b>	5.7	515.7	189.1	-13.3/1.7/34.8/30.1
tr12-30	3/0/0	<b>53.7</b>	0.2	34.0	<b>3.0</b>	26.3/0.0/-6.8/-46.7
traininstance2	0/2/1	<b>415.7</b>	<b>7.2</b>	1171.6	78.6	-41.4/-54.2/-44.6/-12.7
traininstance6	0/3/0	<b>98.9</b>	<b>0.6</b>	170.7	18.7	78.6/50.0/44.2/55.6
trento1	3/0/0	<b>265.2</b>	8.7	<b>13.5</b>	0.0	-29.4/-8.0/-31.1/0.0
triptim1	0/3/0	0.1	22.6	<b>4.6</b>	0.0	0.0/3.0/-13.0/0.0
uccase12	3/0/0	1.9	10.8	16.6	0.0	0.0/-4.6/-6.0/0.0
uccase9	3/0/0	<b>1441.5</b>	<b>30.6</b>	91.8	34.5	74.3/47.2/51.6/52.7
uct-subprob	3/0/0	<b>16.0</b>	<b>0.5</b>	<b>9.3</b>	0.0	-22.5/16.7/-17.2/0.0
unitcal-7	0/0/3	<b>32.2</b>	139.3	1063.8	122.7	-16.8/-1.1/-6.8/15.9
var-smallemercy-m6j6	3/0/0	<b>205.2</b>	25.1	73.3	10.3	19.9/-4.4/-7.9/-1.9
vpm2	3/0/0	<b>38.1</b>	0.1	<b>27.2</b>	<b>0.3</b>	15.3/0.0/-25.0/-100.0
wachplan	0/3/0	0.0	2.7	28.3	0.0	0.0/10.0/-6.4/0.0
Geom. means			(271 instances)	(227 instances)		
FP		44.8	5.4	15.4	1.1	
FP+(3,l,g)		<b>40.6</b>	<b>5.7</b>	<b>16.7</b>	<b>1.3</b>	

Table A.9.: Performance of FP+(5,l,g)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	3/0/0	<b>5.2</b>	<b>1.9</b>	<b>36.0</b>	<b>0.0</b>	57.0/84.4/77.4/100.0
30n20b8	0/3/0	<b>316.9</b>	<b>11.0</b>	<b>388.2</b>	<b>78.6</b>	31.4/-48.2/-57.0/-63.2
50v-10	0/3/0	<b>140.0</b>	0.3	23.3	<b>0.6</b>	-10.9/0.0/-1.3/-50.0
CMS750-4	2/1/0	<b>67.8</b>	<b>10.4</b>	<b>175.7</b>	<b>18.9</b>	-21.8/-60.6/-62.9/-36.5
a1c1s1	3/0/0	<b>27.7</b>	<b>0.6</b>	34.7	<b>3.3</b>	47.5/-33.3/-9.8/-60.6
academic timetable small	0/0/2	inf	496.2	988.9	1.0	-/-/-/-
afLOW30a	3/0/0	141.1	<b>0.2</b>	<b>39.8</b>	<b>4.3</b>	-6.7/-50.0/-15.8/-53.5
afLOW40b	3/0/0	<b>247.8</b>	<b>0.4</b>	<b>38.3</b>	<b>4.6</b>	-16.3/-25.0/-16.4/-67.4
air04	3/0/0	<b>1.0</b>	<b>3.5</b>	<b>15.1</b>	<b>0.3</b>	-90.0/-25.7/-56.3/-100.0

(continued)

Table A.9 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
air05	3/0/0	<b>3.6</b>	<b>1.2</b>	<b>7.3</b>	0.0	12.2/-33.3/-45.2/0.0
app1-1	3/0/0	<b>33.3</b>	<b>0.6</b>	<b>39.4</b>	<b>5.9</b>	-90.7/-16.7/-12.2/-32.2
app1-2	0/2/1	43.9	<b>47.9</b>	247.4	138.1	0.0/-77.7/-79.1/-88.9
arki001	0/1/2	3.1	<b>29.0</b>	1059.5	273.5	-6.5/-28.6/-24.1/-31.8
assign1-5-8	3/0/0	<b>1.3</b>	0.1	22.3	0.0	31.6/0.0/0.0/0.0
atlanta-ip	3/0/0	<b>15.5</b>	17.7	28.5	<b>0.0</b>	13.9/-4.5/-9.5/100.0
b1c1s1	3/0/0	<b>190.9</b>	<b>0.7</b>	<b>39.0</b>	<b>4.9</b>	-15.5/-28.6/-13.6/-26.5
bab2	1/0/2	<b>16.7</b>	<b>565.3</b>	443.4	36.8	34.5/-44.4/-61.0/-36.1
bab6	1/0/2	<b>19.5</b>	<b>301.0</b>	398.3	76.0	17.7/-65.3/-78.0/-79.9
beasleyC3	3/0/0	<b>13.0</b>	<b>0.3</b>	<b>41.0</b>	<b>7.0</b>	-10.8/-33.3/-14.6/-31.4
binkar10-1	3/0/0	3.9	0.1	<b>7.7</b>	0.0	2.5/0.0/51.0/0.0
blp-ar98	3/0/0	71.2	1.9	15.6	0.0	0.1/5.0/7.7/0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/0	-	-	-	-	-/-/-/-
bppc4-08	3/0/0	<b>43.1</b>	1.1	65.6	<b>11.6</b>	16.5/8.3/-5.0/-19.8
brazil3	0/3/0	<b>313.2</b>	<b>18.0</b>	<b>30.4</b>	0.0	50.6/14.7/-29.6/0.0
buildingenergy	0/3/0	1.1	637.5	11.0	0.0	0.0/8.5/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.8	40.7	10.7	0.0/-3.6/-1.7/-6.5
chromaticindex1024-7	3/0/0	0.0	54.8	<b>2.3</b>	0.0	0.0/0.0/23.3/0.0
chromaticindex512-7	3/0/0	0.0	45.0	2.0	0.0	0.0/0.0/0.0/0.0
cmflsp50-24-8-8	0/2/1	18.5	<b>62.1</b>	468.3	140.5	5.1/62.9/55.4/52.3
co-100	3/0/0	302.4	6.2	15.9	0.0	0.1/-1.6/-1.9/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	3349.9	6.3	25.3	0.0	2.2/-1.6/-5.1/0.0
comp21-2idx	0/3/0	443.5	4.8	<b>28.1</b>	0.0	-3.7/-4.2/-10.7/0.0
cost266-UUE	3/0/0	33.8	<b>0.5</b>	<b>29.2</b>	0.3	3.7/-20.0/-19.5/0.0
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/2/1	<b>51.3</b>	<b>10.7</b>	1142.5	287.4	25.7/-43.0/-66.5/-82.8
csched008	2/1/0	9.4	1.6	<b>173.9</b>	<b>43.8</b>	4.1/5.9/-12.6/-45.2
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	18.5	16.6	0.0	0.0/1.1/-2.4/0.0
dano3-5	3/0/0	0.2	42.0	<b>34.5</b>	<b>1.7</b>	0.0/4.5/-12.8/-47.1
dano3mip	3/0/0	<b>10.6</b>	<b>154.3</b>	71.3	<b>16.3</b>	38.4/44.9/-1.0/10.9
danoint	2/1/0	<b>178.7</b>	<b>3.0</b>	<b>131.9</b>	<b>47.3</b>	72.6/25.0/-15.5/-12.9
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>6.4</b>	<b>0.4</b>	<b>14.7</b>	0.0	-12.5/-25.0/-11.6/0.0
drayage-25-23	3/0/0	<b>9.1</b>	<b>0.5</b>	16.6	0.0	10.8/-20.0/-1.2/0.0
ds	3/0/0	4945.0	6.0	1.0	0.0	0.0/0.0/0.0/0.0
dws008-01	0/0/3	<b>63.5</b>	67.9	739.4	214.7	33.8/9.0/9.8/8.9
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0	0.0/0.0/0.0/0.0
enlight-hard	0/0/3	0.0	4.4	833.9	268.3	-/-/-/-
exp-1-500-5-5	3/0/0	<b>115.0</b>	0.1	29.3	<b>0.3</b>	-34.4/0.0/-8.2/-100.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>1171.2</b>	<b>0.5</b>	<b>29.7</b>	<b>1.3</b>	-22.5/-20.0/-31.6/-100.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>11.6</b>	7.2	53.7	<b>5.3</b>	32.6/-2.8/4.1/-13.2
fiber	3/0/0	160.5	0.1	16.3	0.0	-4.3/0.0/-8.6/0.0
fixnet6	3/0/0	<b>58.3</b>	0.1	31.0	1.0	-26.9/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>13.5</b>	0.1	<b>4.5</b>	0.0	-22.2/0.0/-35.6/0.0
germanrr	0/3/0	<b>7.1</b>	<b>16.1</b>	<b>93.7</b>	<b>15.4</b>	-42.3/-27.3/-45.8/-61.7
gesa2	0/3/0	2.4	0.2	<b>27.2</b>	<b>0.3</b>	0.0/0.0/-25.0/-100.0
gesa2-o	0/3/0	<b>14.8</b>	0.2	34.6	1.6	26.0/0.0/2.8/-6.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	1/2/0	<b>300.1</b>	<b>0.5</b>	<b>174.6</b>	<b>71.4</b>	56.0/-40.0/-40.3/-54.9
gmu-35-40	3/0/0	6.5	0.1	14.0	0.0	0.0/0.0/0.0/0.0
gmu-35-50	3/0/0	<b>9.8</b>	<b>0.5</b>	<b>52.1</b>	<b>6.5</b>	19.7/-40.0/-39.7/-84.6
graph20-20-1rand	3/0/0	<b>22.2</b>	<b>4.8</b>	<b>54.1</b>	<b>1.1</b>	-36.9/-14.6/-42.1/-63.6

(continued)

Table A.9 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
graphdraw-domain	0/3/0	<b>254.8</b>	<b>0.6</b>	<b>126.1</b>	<b>41.4</b>	-88.7/-50.0/-51.9/-74.9
h80x6320d	3/0/0	22.2	1.2	32.3	<b>2.3</b>	-0.9/0.0/-0.9/-17.4
harp2	3/0/0	11.5	0.1	13.3	0.0	7.3/0.0/-4.5/0.0
highschool1-aigio	0/3/0	inf	735.5	<b>23.2</b>	0.0	0.0/-6.4/-34.1/0.0
hypothyroid-k1	3/0/0	0.0	4.7	1.0	0.0	0.0/2.1/0.0/0.0
ic97p	0/1/2	<b>13.7</b>	<b>4.4</b>	622.2	216.3	11.0/13.7/29.8/-5.0
ic97t	0/0/3	12.5	<b>5.7</b>	1787.2	528.0	-0.8/-31.6/-29.1/-41.1
icir97p	0/0/3	<b>19.4</b>	<b>34.9</b>	1142.9	218.1	15.3/-38.1/-0.3/-1.1
icir97t	0/3/0	<b>13.4</b>	<b>8.1</b>	<b>235.0</b>	133.8	14.6/-45.7/-10.4/-3.7
irish-electricity	3/0/0	6.2	<b>22.1</b>	25.6	0.3	-3.2/-12.2/-5.5/0.0
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>15.3</b>	6.5	22.6	0.0	57.5/-1.5/-2.7/0.0
k1mushroom	3/0/0	18.2	40.5	1.0	0.0	0.0/-1.7/0.0/0.0
lectsched-5-obj	0/0/3	<b>2501.0</b>	<b>96.2</b>	995.3	3.4	-10.2/-12.7/-8.7/51.4
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	674.7	1.2	90.0	57.7	0.0/-8.3/0.0/-1.9
lotsize	2/0/1	<b>182.1</b>	<b>2.0</b>	145.0	45.0	-61.2/-75.0/-69.0/-76.7
mad	3/0/0	<b>6573.5</b>	0.1	16.0	0.0	46.8/0.0/-8.1/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>22.3</b>	52.9	<b>72.3</b>	<b>21.3</b>	50.1/-5.7/-50.5/-85.0
map16715-04	3/0/0	<b>70.7</b>	56.7	<b>54.9</b>	<b>11.4</b>	20.7/0.4/-15.7/-20.2
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>232.3</b>	0.2	90.0	<b>9.3</b>	51.2/0.0/0.0/36.3
mas76	0/3/0	<b>293.3</b>	0.2	90.0	<b>10.2</b>	-63.9/0.0/0.8/52.6
mc11	3/0/0	104.9	<b>0.5</b>	<b>49.3</b>	<b>14.3</b>	3.0/-20.0/-13.6/-14.0
mcsched	3/0/0	<b>15.6</b>	0.5	4.0	0.0	-17.3/0.0/-10.0/0.0
mik-250-20-75-4	0/3/0	<b>42.4</b>	0.2	<b>21.5</b>	<b>2.3</b>	30.6/0.0/43.9/48.9
milo-v12-6-r2-40-1	3/0/0	<b>76.9</b>	1.0	<b>48.3</b>	12.0	48.8/-10.0/-13.0/0.0
misc07	3/0/0	29.9	<b>0.2</b>	<b>24.6</b>	<b>0.6</b>	-4.3/-50.0/-18.3/-100.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>34.6</b>	<b>0.4</b>	20.7	0.0	-59.5/-25.0/-5.3/0.0
modglob	3/0/0	<b>121.9</b>	0.1	31.7	1.3	-13.1/0.0/-1.3/0.0
momentum1	0/1/2	193.7	<b>69.6</b>	1086.4	553.9	-0.2/-43.2/-48.6/-36.3
msc98-ip	3/0/0	15.7	6.9	<b>36.2</b>	<b>1.6</b>	-1.3/-8.7/-15.2/-62.5
mushroom-best	0/3/0	<b>1.25e07</b>	<b>18.5</b>	<b>53.6</b>	<b>1.5</b>	-26.6/-26.5/-25.4/11.8
mzzv11	0/3/0	19.4	4.0	<b>23.1</b>	<b>0.3</b>	3.5/4.8/-16.5/-100.0
mzzv42z	0/3/0	<b>26.5</b>	<b>3.9</b>	<b>21.3</b>	<b>0.0</b>	14.5/20.4/10.5/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>27.7</b>	<b>0.5</b>	<b>33.0</b>	<b>2.0</b>	-66.1/-40.0/-38.2/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>7.5</b>	5.1	<b>30.5</b>	<b>1.3</b>	-88.0/-3.9/-13.4/-53.8
neos-1171737	3/0/0	<b>4.9</b>	<b>1.8</b>	<b>33.0</b>	<b>2.0</b>	-20.4/-11.1/-10.3/-70.0
neos-1354092	0/3/0	<b>8.1</b>	161.2	40.6	0.0	55.2/8.6/-7.4/0.0
neos-1445765	3/0/0	34.9	<b>0.7</b>	5.8	0.0	1.4/12.5/-3.4/0.0
neos-1456979	0/2/1	<b>112.0</b>	<b>32.5</b>	459.3	116.8	25.3/19.6/0.7/-17.4
neos-1582420	0/3/0	<b>81.7</b>	<b>3.1</b>	<b>200.5</b>	<b>24.1</b>	-15.5/-51.6/-60.3/-61.0
neos-2657525-crna	0/3/0	960.7	<b>0.1</b>	<b>25.6</b>	<b>1.2</b>	5.5/50.0/38.8/40.0
neos-2746589-doon	0/0/3	<b>7.0</b>	<b>322.7</b>	717.3	26.2	79.9/-57.2/-65.4/16.3
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	1/2/0	<b>0.2</b>	<b>13.3</b>	<b>79.0</b>	<b>23.7</b>	33.3/-28.6/-31.3/-37.6
neos-3004026-krka	0/0/3	0.0	<b>130.7</b>	1543.6	3.3	0.0/-16.6/-16.7/8.3
neos-3024952-loue	0/1/2	<b>927.3</b>	<b>283.5</b>	1899.4	36.5	-12.3/-71.8/-25.5/-23.8
neos-3046615-murg	0/3/0	<b>7391.8</b>	0.2	94.8	63.3	32.2/0.0/-0.5/3.5
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	<b>134.4</b>	<b>143.8</b>	1070.9	272.4	-10.0/68.6/2.3/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>33.3</b>	1148.9	0.0	0.0/-45.0/-8.3/100.0
neos-3402294-bobin	3/0/0	<b>508.4</b>	<b>30.9</b>	<b>37.5</b>	<b>0.6</b>	-15.6/-35.0/-49.1/-100.0

(continued)

Table A.9 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-3555904-turama	3/0/0	<b>4.3</b>	73.2	32.1	<b>0.6</b>	-53.5/6.4/-2.2/-33.3
neos-3627168-kasai	3/0/0	1.6	<b>0.2</b>	<b>27.2</b>	<b>0.3</b>	-6.3/-50.0/-25.0/-100.0
neos-3656078-kumeu	0/0/3	<b>23.8</b>	<b>171.6</b>	1379.3	0.4	22.7/-18.2/-24.5/55.6
neos-3754480-nidda	3/0/0	<b>414.8</b>	0.2	67.3	<b>10.3</b>	-11.9/0.0/0.6/24.3
neos-4300652-rahue	0/1/2	<b>193.5</b>	<b>314.9</b>	363.1	1.0	27.2/23.7/-2.3/-70.0
neos-4338804-snowy	0/3/0	<b>1.33e05</b>	<b>1.6</b>	<b>182.8</b>	<b>49.3</b>	-14.3/-50.0/-45.0/-43.2
neos-4387871-tavua	0/1/2	803.9	<b>12.7</b>	508.8	265.8	-6.1/44.5/36.6/37.8
neos-4413714-turia	3/0/0	<b>9.6</b>	74.4	73.6	12.5	78.1/6.9/7.7/3.8
neos-4532248-waihi	1/0/2	949.4	447.0	420.2	69.1	0.0/8.6/4.4/-47.8
neos-4647030-tutaki	3/0/0	<b>13.5</b>	<b>24.8</b>	<b>27.0</b>	0.0	38.6/-29.4/-34.4/0.0
neos-4722843-widden	0/3/0	<b>53.3</b>	<b>26.4</b>	<b>49.3</b>	<b>8.0</b>	73.0/52.1/46.6/68.8
neos-4738912-atrato	0/3/0	<b>5.6</b>	<b>0.4</b>	<b>21.5</b>	0.0	53.3/-25.0/-42.3/0.0
neos-4763324-toguru	3/0/0	55.6	20.8	23.3	0.0	6.1/1.4/1.7/0.0
neos-4954672-berkel	3/0/0	51.0	0.1	<b>39.0</b>	<b>4.9</b>	6.8/0.0/-17.9/-73.5
neos-5049753-cuanza	1/1/1	<b>56.5</b>	717.8	324.2	84.0	25.3/6.8/0.4/-14.3
neos-5052403-cygnat	3/0/0	<b>0.6</b>	41.2	2.3	0.0	53.8/2.1/0.0/0.0
neos-5093327-huahum	3/0/0	<b>35.5</b>	<b>7.6</b>	<b>81.3</b>	<b>48.3</b>	96.1/43.3/32.6/44.2
neos-5104907-jarama	0/1/1	68.8	1356.9	513.7	116.4	-/-/-/-
neos-5107597-kakapo	2/1/0	<b>34168.6</b>	<b>2.9</b>	<b>214.9</b>	<b>175.7</b>	13.1/-37.9/-42.6/-46.0
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	4248.9	<b>4.6</b>	25.3	0.0	-5.6/19.3/5.2/0.0
neos-5195221-niemur	3/0/0	<b>944.1</b>	7.4	19.4	0.0	-18.7/0.0/-3.6/0.0
neos-631710	3/0/0	149.4	2.3	1.0	0.0	0.0/8.0/0.0/0.0
neos-662469	0/3/0	<b>284.1</b>	<b>5.7</b>	18.0	<b>0.8</b>	-21.5/10.9/6.7/-12.5
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>5.47e05</b>	102.3	70.9	19.6	-45.9/1.0/-2.3/5.3
neos-860300	3/0/0	<b>64.9</b>	<b>0.5</b>	<b>6.0</b>	0.0	-12.2/-20.0/-33.3/0.0
neos-873061	3/0/0	58.5	<b>28.7</b>	33.0	<b>2.0</b>	4.4/-10.5/-3.9/-20.0
neos-911970	3/0/0	<b>189.9</b>	0.2	54.0	<b>4.8</b>	-30.5/0.0/-7.4/20.0
neos-933966	3/0/0	<b>197.6</b>	1.5	<b>10.5</b>	0.0	11.8/6.3/-10.5/0.0
neos-950242	3/0/0	131.2	<b>12.6</b>	<b>40.3</b>	<b>2.6</b>	-2.2/-46.8/-45.9/-84.6
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	0/3/0	<b>1.5</b>	<b>55.5</b>	<b>224.3</b>	<b>13.8</b>	34.8/-63.6/-72.4/-84.8
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<b>2.2</b>	<b>14.5</b>	1441.3	6.3	-36.4/-35.9/-18.9/-58.7
neos17	3/0/0	299.4	0.2	33.3	<b>2.2</b>	-3.1/0.0/-4.8/-27.3
neos20	0/1/2	<b>60.8</b>	<b>11.5</b>	1285.5	126.7	-24.8/-14.8/-8.1/-35.8
neos5	3/0/0	<b>85.4</b>	0.1	<b>3.3</b>	0.0	-51.3/0.0/13.2/0.0
neos7	0/3/0	11.7	<b>0.4</b>	<b>38.7</b>	<b>2.2</b>	-6.0/-50.0/-35.4/-100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>24.2</b>	<b>3.4</b>	<b>19.3</b>	0.0	36.8/20.9/24.9/0.0
netdiversion	3/0/0	82.9	<b>62.4</b>	<b>7.1</b>	0.0	4.1/16.7/26.0/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	<b>8.7</b>	<b>18.5</b>	894.5	210.0	14.7/-26.5/18.1/18.9
nh97t	0/1/2	10.7	<b>19.1</b>	936.5	218.0	-0.9/-33.0/14.2/33.3
noswot	0/3/0	<b>23.6</b>	0.1	<b>50.7</b>	<b>6.7</b>	-59.3/0.0/-32.3/-80.6
ns1116954	0/1/2	0.0	<b>619.0</b>	750.0	7.3	0.0/-23.8/-37.7/-56.2
ns1208400	0/3/0	0.0	<b>59.5</b>	438.6	<b>0.8</b>	0.0/34.0/-9.8/-62.5
ns1644855	3/0/0	<b>10.8</b>	<b>596.9</b>	<b>51.6</b>	<b>7.5</b>	-95.4/-34.6/-33.1/-77.3
ns1760995	3/0/0	<b>11.0</b>	76.9	75.3	<b>3.3</b>	26.2/9.1/6.5/-12.1
ns1830653	0/3/0	<b>527.8</b>	<b>8.2</b>	<b>250.9</b>	<b>31.7</b>	-68.9/-46.3/-76.6/-96.8
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ixp	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.6	0.3	18.6	0.0	-8.3/0.0/2.1/0.0
nursesched-medium-hint03	0/3/0	786.1	<b>20.8</b>	<b>25.6</b>	0.0	0.0/-33.2/-55.5/0.0
nursesched-sprint02	0/3/0	55.2	<b>2.8</b>	<b>15.3</b>	0.0	0.0/-32.1/-39.2/0.0
nw04	3/0/0	3.9	<b>2.3</b>	<b>9.3</b>	0.0	0.0/-13.0/-14.0/0.0
opm2-z10-s4	3/0/0	94.2	27.1	1.0	0.0	0.0/0.7/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	0.1	<b>42.3</b>	<b>3.2</b>	100.0/0.0/-14.2/-28.1
p200x1188c	3/0/0	<b>4.4</b>	0.2	31.0	1.0	-11.4/0.0/0.0/0.0

(continued)

Table A.9 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/-
pg	3/0/0	<b>4.6</b>	0.3	56.8	20.1	70.3/0.0/-9.0/-4.5
pg5-34	3/0/0	<b>4.9</b>	0.4	53.7	12.9	31.0/0.0/-3.2/5.1
physiciansched3-3	3/0/0	<b>5.6</b>	50.3	44.2	<b>1.9</b>	35.6/7.7/3.9/-47.4
physiciansched6-2	0/0/3	<b>4.1</b>	<b>74.7</b>	1080.9	95.4	16.3/11.5/-31.5/-63.5
piperout-08	0/0/3	<b>17.8</b>	<b>34.1</b>	797.5	34.6	95.5/50.7/53.4/-3.8
piperout-27	0/0/3	221.2	<b>86.3</b>	1543.3	23.8	3.2/-23.5/-22.4/-26.1
pk1	3/0/0	<b>665.4</b>	0.2	62.6	8.4	44.2/0.0/-7.3/5.6
pp08a	3/0/0	<b>77.3</b>	0.1	<b>20.4</b>	0.0	-24.5/0.0/-23.5/0.0
pp08aCUTS	3/0/0	31.9	0.1	<b>20.4</b>	0.0	9.1/0.0/-41.2/0.0
proteindesign121hz512p9	0/3/0	2.4	4.8	22.5	<b>0.0</b>	0.0/4.0/7.8/100.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	2/1/0	63.8	<b>9.8</b>	<b>69.8</b>	<b>4.4</b>	3.3/-14.3/-45.8/-100.0
qap10	3/0/0	19.4	13.7	2.0	0.0	0.0/0.0/0.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	258.5	<b>0.6</b>	26.7	<b>1.1</b>	-7.1/-16.7/-5.2/-100.0
rB10-011001	3/0/0	204.1	<b>0.6</b>	28.1	<b>0.4</b>	0.0/-16.7/-6.4/-100.0
rB11-010000	3/0/0	<b>324.2</b>	1.3	28.0	<b>0.4</b>	-11.0/0.0/6.7/33.3
rB11-110001	3/0/0	193.4	2.8	<b>26.5</b>	<b>0.4</b>	6.8/-7.1/-12.1/-25.0
rB12-111111	1/2/0	82.7	<b>19.3</b>	279.4	8.7	8.0/58.4/51.4/-63.2
rC10-001000	3/0/0	<b>132.1</b>	<b>0.3</b>	28.9	0.0	52.0/-33.3/-3.5/0.0
rC10-100001	3/0/0	445.8	5.3	108.5	<b>1.0</b>	-8.4/-7.5/-6.5/-20.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>205.2</b>	<b>11.8</b>	<b>87.7</b>	<b>0.6</b>	36.2/-56.8/-58.5/25.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>267.9</b>	<b>4.2</b>	<b>130.3</b>	<b>12.1</b>	-43.2/-57.1/-47.6/-70.2
radiationm40-10-02	0/3/0	<b>5051.5</b>	<b>37.2</b>	<b>346.5</b>	<b>39.9</b>	-91.5/-56.5/-58.5/-77.4
rail01	3/0/0	30.3	<b>1091.9</b>	<b>16.9</b>	0.0	2.3/14.7/-29.6/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<b>24.8</b>	0.3	21.2	<b>0.0</b>	-33.1/0.0/7.0/100.0
rd-rplusc-21	0/0/3	57.6	32.6	826.2	364.9	0.9/9.9/4.7/-1.2
reblock115	3/0/0	<b>7.7</b>	1.7	<b>63.3</b>	<b>7.8</b>	31.2/-5.9/-12.5/-20.5
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.0	2.0	0.0	0.0/0.7/0.0/0.0
rocl-4-11	0/0/3	<b>55.0</b>	<b>18.8</b>	753.7	110.6	20.5/11.3/19.1/-6.1
rocll-5-11	0/1/2	85.6	<b>32.5</b>	663.0	263.0	5.3/-74.2/-76.5/-80.0
roi2alpha3n4	3/0/0	<b>44.3</b>	<b>40.4</b>	<b>39.6</b>	<b>3.6</b>	29.0/-17.6/-13.4/-55.6
roi5alpha10n8	3/0/0	60.5	<b>585.2</b>	<b>36.6</b>	<b>1.5</b>	-0.7/-23.7/-20.8/-100.0
roll3000	0/3/0	<b>31.9</b>	1.1	<b>57.7</b>	<b>7.4</b>	-17.9/0.0/-16.1/-39.2
rout	0/3/0	44.8	0.2	37.2	<b>2.4</b>	9.5/0.0/-5.4/-29.2
s100	3/0/0	<b>2.8</b>	<b>250.0</b>	<b>4.0</b>	0.0	-39.3/17.4/39.4/0.0
s250r10	3/0/0	0.1	53.2	2.0	0.0	0.0/0.4/0.0/0.0
satellites2-40	0/3/0	<b>422.2</b>	<b>71.5</b>	<b>147.0</b>	<b>57.0</b>	-41.9/-38.2/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>93.0</b>	409.8	182.5	-60.0/-75.7/-91.5/-98.5
savsched1	0/3/0	8.5	199.0	13.0	0.0	-7.1/-4.5/-5.4/0.0
sct2	3/0/0	<b>25.8</b>	<b>0.7</b>	<b>30.4</b>	0.6	11.6/-14.3/-14.1/0.0
set1ch	3/0/0	<b>56.0</b>	0.1	31.0	1.0	34.6/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<b>8.5</b>	<b>3.2</b>	<b>9.2</b>	0.0	-83.5/-15.6/-17.4/0.0
sing326	3/0/0	<b>14.6</b>	<b>30.9</b>	<b>42.3</b>	<b>4.5</b>	-27.4/-20.1/-19.6/-64.4
sing44	3/0/0	<b>6.6</b>	27.9	41.7	<b>4.6</b>	10.8/-5.4/-7.7/-17.4
snp-02-004-104	0/3/0	1.7	20.3	34.3	<b>2.6</b>	0.0/-3.0/-2.0/-26.9
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.7	<b>1.6</b>	0.0/0.0/-1.3/-18.8
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.2	<b>55.0</b>	<b>8.0</b>	0.0	-0.6/11.4/38.5/0.0
square41	0/3/0	6.7	<b>1452.2</b>	11.0	0.0	0.0/-15.9/-9.1/0.0

(continued)

Table A.9 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>132.2</b>	112.9	<b>12.0</b>	0.0	22.4/-2.5/11.8/0.0
supportcase12	0/3/0	<b>2.1</b>	<b>16.6</b>	<b>24.8</b>	0.0	-14.3/-12.0/-15.3/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>819.2</b>	<b>0.3</b>	90.0	59.7	91.3/-33.3/-0.3/5.7
supportcase33	0/3/0	<b>56.5</b>	<b>24.3</b>	<b>285.9</b>	<b>41.6</b>	12.4/-43.2/-57.6/-65.1
supportcase40	3/0/0	<b>42.6</b>	<b>4.7</b>	<b>20.6</b>	0.0	-58.7/-10.6/-19.4/0.0
supportcase42	0/3/0	<b>14.3</b>	<b>5.2</b>	<b>13.9</b>	0.0	41.4/-19.2/-16.5/0.0
supportcase6	3/0/0	<b>0.6</b>	<b>15.6</b>	<b>14.8</b>	0.0	-33.3/-14.7/-18.9/0.0
supportcase7	3/0/0	<b>10.5</b>	9.1	26.0	0.0	26.6/-8.8/0.0/0.0
swath	0/3/0	176.5	<b>26.0</b>	<b>354.4</b>	<b>134.6</b>	2.8/-48.1/-47.0/-55.7
swath1	3/0/0	<b>24.7</b>	<b>1.1</b>	<b>41.9</b>	<b>5.3</b>	59.1/52.2/32.6/66.2
swath3	3/0/0	<b>22.8</b>	<b>1.1</b>	41.6	<b>5.2</b>	31.3/26.7/3.0/-38.5
t1717	3/0/0	<b>146.0</b>	117.0	<b>51.2</b>	0.0	18.5/7.4/-15.0/0.0
tbfp-network	3/0/0	<b>41.0</b>	<b>15.1</b>	<b>12.5</b>	0.0	79.4/32.6/10.7/0.0
thor50dday	3/0/0	<b>306.6</b>	7.7	25.5	<b>1.9</b>	-15.9/-6.5/-3.9/-10.5
timtab1	0/3/0	<b>73.6</b>	<b>1.1</b>	<b>137.5</b>	<b>58.8</b>	-24.6/-45.5/-17.3/-52.6
timtab2	0/2/1	<b>85.2</b>	<b>12.3</b>	906.2	317.7	-13.6/-52.8/-12.7/-14.9
tr12-30	3/0/0	<b>43.9</b>	0.2	<b>36.8</b>	<b>3.6</b>	39.8/0.0/-13.9/-55.6
traininstance2	0/2/1	<b>555.5</b>	<b>4.6</b>	661.3	106.3	-56.1/-28.3/-1.8/-35.5
traininstance6	0/3/0	<b>901.8</b>	<b>1.0</b>	241.1	29.7	-48.8/16.7/21.2/29.5
trento1	3/0/0	<b>272.4</b>	8.2	<b>11.3</b>	0.0	-31.3/-2.4/-17.7/0.0
triptim1	0/3/0	0.1	22.2	3.9	0.0	0.0/4.7/2.5/0.0
uccase12	3/0/0	1.9	10.8	16.6	0.0	0.0/-4.6/-6.0/0.0
uccase9	3/0/0	<b>4552.2</b>	<b>32.8</b>	101.3	41.3	18.8/43.4/46.6/43.4
uct-subprob	3/0/0	<b>15.3</b>	<b>0.5</b>	<b>10.0</b>	0.0	-19.0/16.7/-23.0/0.0
unitcal-7	0/0/3	<b>18.8</b>	<b>104.1</b>	764.3	47.7	29.9/24.4/22.9/67.3
var-smallemergy-m6j6	3/0/0	<b>13.0</b>	24.5	70.6	<b>11.3</b>	94.9/-2.0/-4.4/-10.6
vpm2	3/0/0	44.3	0.1	<b>28.6</b>	<b>0.3</b>	1.6/0.0/-28.7/-100.0
wachplan	0/3/0	0.0	3.2	<b>37.4</b>	0.0	0.0/-6.3/-29.1/0.0
Geom. means		(271 instances)	(229 instances)			
FP		45.7	5.4	16.0	1.1	
FP+(5,l,g)		<b>43.4</b>	<b>5.8</b>	<b>18.2</b>	<b>1.5</b>	

Table A.10.: Performance of FP+(10,l,g)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	3/0/0	<b>1.1</b>	<b>0.5</b>	<b>8.0</b>	<b>0.0</b>	90.9/95.9/95.0/100.0
30n20b8	0/1/2	<b>383.4</b>	<b>25.2</b>	844.8	211.5	17.0/-77.4/-80.2/-86.3
50v-10	0/3/0	<b>141.7</b>	<b>0.4</b>	23.3	<b>0.6</b>	-12.0/-25.0/-1.3/-50.0
CMS750-4	3/0/0	<b>72.2</b>	<b>10.6</b>	<b>173.1</b>	<b>17.8</b>	-26.6/-61.3/-62.4/-32.6
a1c1s1	3/0/0	<b>23.2</b>	<b>0.6</b>	<b>35.0</b>	<b>3.3</b>	56.1/-33.3/-10.6/-60.6
academictimetablesmall	0/0/3	inf	570.1	1199.2	7.2	-/-/-/-
aflow30a	3/0/0	127.6	<b>0.2</b>	<b>41.7</b>	<b>4.4</b>	3.0/-50.0/-19.7/-54.5
aflow40b	3/0/0	195.7	0.3	34.0	<b>2.6</b>	5.6/0.0/-5.9/-42.3
air04	3/0/0	<b>0.8</b>	<b>3.3</b>	<b>12.2</b>	<b>0.3</b>	-87.5/-21.2/-45.9/-100.0
air05	3/0/0	<b>2.6</b>	<b>1.2</b>	<b>7.1</b>	0.0	36.6/-33.3/-43.7/0.0
app1-1	2/1/0	<b>42.0</b>	<b>1.1</b>	<b>62.2</b>	<b>15.3</b>	-92.6/-54.5/-44.4/-73.9
app1-2	0/2/1	43.9	<b>45.8</b>	239.7	121.9	0.0/-76.6/-78.4/-87.4
arki001	0/2/1	3.0	<b>28.0</b>	979.6	260.9	-3.3/-26.1/-17.9/-28.6
assign1-5-8	3/0/0	<b>2.5</b>	0.1	23.3	0.0	-24.0/0.0/-4.3/0.0
atlanta-ip	3/0/0	<b>10.7</b>	15.9	<b>19.9</b>	<b>0.0</b>	40.6/5.9/22.9/100.0
b1c1s1	3/0/0	165.5	<b>1.0</b>	<b>42.3</b>	<b>7.0</b>	-2.5/-50.0/-20.3/-48.6
bab2	1/0/2	<b>15.0</b>	<b>523.5</b>	406.0	21.2	41.2/-40.0/-57.4/9.8
bab6	0/0/3	<b>12.5</b>	<b>518.8</b>	769.5	264.9	47.3/-79.9/-88.6/-94.2
beasleyC3	3/0/0	11.9	<b>0.3</b>	<b>52.6</b>	<b>12.3</b>	-2.5/-33.3/-33.5/-61.0
binkar10-1	3/0/0	3.9	0.1	<b>7.7</b>	0.0	2.5/0.0/51.0/0.0

(continued)



Table A.10 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
blp-ar98	3/0/0	70.1	2.2	17.8	0.0	1.7/-9.1/-5.1/0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/0	-	-	-	-	-/-/-/-
bppc4-08	3/0/0	<b>37.5</b>	1.1	60.2	<b>7.1</b>	27.3/8.3/3.4/23.7
brazil3	0/3/0	<b>506.1</b>	21.9	<b>27.2</b>	0.0	20.2/-3.7/-21.3/0.0
buildingenergy	0/3/0	1.1	<b>617.8</b>	11.0	0.0	0.0/11.3/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.8	41.7	10.7	0.0/-3.6/-4.1/-6.5
chromaticindex1024-7	3/0/0	0.0	54.4	<b>2.3</b>	0.0	0.0/0.7/23.3/0.0
chromaticindex512-7	3/0/0	0.0	45.3	2.0	0.0	0.0/-0.7/0.0/0.0
cmflsp50-24-8-8	2/0/1	<b>15.5</b>	<b>32.5</b>	237.0	71.2	20.5/80.6/77.4/75.8
co-100	3/0/0	287.3	6.0	15.6	0.0	5.1/1.6/0.0/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	3401.0	6.2	25.3	0.0	0.8/0.0/-5.1/0.0
comp21-2idx	0/3/0	<b>382.5</b>	4.8	<b>28.1</b>	0.0	10.4/-4.2/-10.7/0.0
cost266-UUE	3/0/0	38.1	<b>0.5</b>	<b>31.1</b>	<b>1.1</b>	-7.9/-20.0/-24.4/-72.7
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/2/1	<b>54.4</b>	<b>9.4</b>	964.2	238.7	21.2/-35.1/-60.3/-79.3
csched008	2/1/0	9.2	<b>1.1</b>	<b>115.9</b>	<b>16.9</b>	6.1/35.3/23.7/29.6
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	17.9	<b>18.0</b>	0.0	0.0/4.3/-10.0/0.0
dano3-5	3/0/0	<b>0.1</b>	40.0	<b>34.6</b>	<b>2.2</b>	50.0/9.1/-13.0/-59.1
dano3mip	3/0/0	<b>14.6</b>	<b>140.8</b>	70.7	17.0	15.1/49.8/-0.1/7.1
danooint	2/1/0	<b>161.5</b>	<b>2.5</b>	111.6	38.9	75.2/37.5/-0.1/5.6
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>6.4</b>	<b>0.4</b>	<b>14.7</b>	0.0	-12.5/-25.0/-11.6/0.0
drayage-25-23	3/0/0	<b>5.0</b>	<b>0.6</b>	<b>21.5</b>	0.0	51.0/-33.3/-23.7/0.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0
dws008-01	0/0/3	<b>29.9</b>	68.2	1027.0	331.1	68.8/8.6/-20.2/-28.8
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.0	1.0	0.0	0.0/9.1/0.0/0.0
enlight-hard	0/0/3	0.0	5.3	681.2	208.4	-/-/-/-
exp-1-500-5-5	3/0/0	<b>144.6</b>	0.1	<b>30.9</b>	<b>0.4</b>	-47.9/0.0/-12.9/-100.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>708.6</b>	<b>0.3</b>	20.3	0.0	21.9/25.0/0.0/0.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>13.0</b>	7.7	54.6	<b>5.6</b>	24.4/-9.1/2.5/-17.9
fiber	3/0/0	160.5	0.1	16.3	0.0	-4.3/0.0/-8.6/0.0
fixnet6	3/0/0	<b>58.3</b>	0.1	31.0	1.0	-26.9/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>13.5</b>	0.1	<b>4.5</b>	0.0	-22.2/0.0/-35.6/0.0
germanrr	0/3/0	<b>4.6</b>	<b>14.9</b>	<b>82.7</b>	<b>14.3</b>	-10.9/-21.5/-38.6/-58.7
gesa2	0/3/0	2.4	<b>0.3</b>	<b>31.0</b>	<b>0.8</b>	0.0/-33.3/-34.2/-100.0
gesa2-o	0/3/0	<b>15.1</b>	<b>0.3</b>	37.6	<b>1.9</b>	24.5/-33.3/-5.3/-21.1
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	2/1/0	<b>520.8</b>	<b>0.4</b>	<b>138.9</b>	<b>56.4</b>	23.6/-25.0/-25.0/-42.9
gmu-35-40	3/0/0	6.5	0.1	14.0	0.0	0.0/0.0/0.0/0.0
gmu-35-50	3/0/0	<b>7.9</b>	<b>0.5</b>	<b>52.0</b>	<b>6.6</b>	35.2/-40.0/-39.6/-84.8
graph20-20-1rand	3/0/0	<b>25.5</b>	<b>4.8</b>	<b>54.4</b>	<b>1.2</b>	-45.1/-14.6/-42.5/-66.7
graphdraw-domain	0/3/0	<b>115.7</b>	<b>0.4</b>	<b>89.6</b>	<b>22.0</b>	-75.1/-25.0/-32.3/-52.7
h80x6320d	3/0/0	23.5	1.3	<b>35.6</b>	<b>3.6</b>	-6.4/-7.7/-10.1/-47.2
harp2	3/0/0	11.9	0.1	13.0	0.0	4.0/0.0/-2.3/0.0
highschool1-aigio	0/3/0	inf	<b>794.4</b>	<b>24.9</b>	0.0	0.0/-13.3/-38.6/0.0
hypothyroid-k1	3/0/0	0.0	4.6	1.0	0.0	0.0/4.2/0.0/0.0
ic97p	0/1/2	14.9	5.6	602.2	178.7	3.2/-8.9/32.1/13.0
ic97t	0/0/3	13.5	<b>4.9</b>	1353.7	395.1	-8.1/-20.4/-6.4/-21.2
icir97p	0/0/3	<b>19.5</b>	<b>41.9</b>	973.3	202.3	14.8/-48.4/14.6/6.2
icir97t	0/3/0	14.3	<b>15.3</b>	<b>268.4</b>	<b>152.5</b>	8.9/-71.2/-21.6/-15.5
irish-electricity	3/0/0	6.2	<b>24.6</b>	<b>28.0</b>	<b>0.6</b>	-3.2/-21.1/-13.6/-50.0
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0

(continued)

Table A.10 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
istanbul-no-cutoff	3/0/0	<b>17.0</b>	6.6	23.0	0.0	52.8/-3.0/-4.3/0.0
k1mushroom	3/0/0	18.2	39.9	1.0	0.0	0.0/-0.3/0.0/0.0
lectsched-5-obj	0/0/3	2373.7	<b>107.6</b>	1072.1	7.2	-5.4/-21.9/-15.3/-2.8
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>463.7</b>	1.2	90.7	57.6	31.3/-8.3/-0.8/-1.7
lotsize	1/2/0	<b>151.2</b>	<b>1.1</b>	<b>98.4</b>	<b>40.3</b>	-53.2/-54.5/-54.4/-73.9
mad	3/0/0	<b>6573.5</b>	0.1	16.0	0.0	46.8/0.0/-8.1/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>22.9</b>	50.0	<b>64.1</b>	<b>17.0</b>	48.8/-0.2/-44.1/-81.2
map16715-04	3/0/0	91.1	55.8	<b>55.5</b>	<b>11.6</b>	-2.1/1.9/-16.6/-21.6
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>579.8</b>	0.2	90.0	<b>9.3</b>	-17.9/0.0/0.0/36.3
mas76	0/3/0	<b>293.3</b>	0.2	90.0	<b>10.2</b>	-63.9/0.0/0.8/52.6
mc11	3/0/0	115.4	<b>0.7</b>	<b>71.6</b>	<b>22.3</b>	-6.2/-42.9/-40.5/-44.8
mcsched	3/0/0	<b>15.6</b>	<b>0.6</b>	4.0	0.0	-17.3/-16.7/-10.0/0.0
mik-250-20-75-4	0/3/0	<b>54.4</b>	<b>0.3</b>	<b>22.7</b>	<b>2.7</b>	11.0/-33.3/40.7/40.0
milo-v12-6-r2-40-1	3/0/0	<b>58.3</b>	<b>1.5</b>	<b>67.0</b>	<b>19.0</b>	61.2/-40.0/-37.3/-36.8
misc07	3/0/0	<b>23.2</b>	0.1	<b>22.5</b>	0.0	18.9/0.0/-10.7/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>15.8</b>	<b>0.4</b>	20.1	0.0	-11.4/-25.0/-2.5/0.0
modglob	3/0/0	<b>144.8</b>	0.1	32.3	<b>1.5</b>	-26.9/0.0/-3.1/-13.3
momentum1	0/1/2	<b>171.1</b>	<b>53.4</b>	818.1	431.1	11.5/-26.0/-31.8/-18.1
msc98-ip	3/0/0	<b>17.5</b>	<b>7.1</b>	<b>36.2</b>	<b>1.9</b>	-11.4/-11.3/-15.2/-68.4
mushroom-best	0/3/0	<b>4.72e05</b>	<b>16.6</b>	<b>50.6</b>	<b>5.6</b>	94.9/-18.1/-20.9/-69.6
mzzv11	0/3/0	<b>23.4</b>	<b>3.7</b>	<b>22.6</b>	0.0	-14.1/11.9/-14.6/0.0
mzzv42z	0/3/0	<b>27.7</b>	<b>4.2</b>	23.6	<b>0.0</b>	10.6/14.3/0.8/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>16.1</b>	<b>0.5</b>	<b>31.6</b>	<b>1.1</b>	-41.6/-40.0/-35.4/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>7.6</b>	5.1	<b>30.5</b>	<b>1.3</b>	-88.2/-3.9/-13.4/-53.8
neos-1171737	3/0/0	<b>6.4</b>	<b>1.8</b>	<b>33.0</b>	<b>2.0</b>	-39.1/-11.1/-10.3/-70.0
neos-1354092	0/3/0	<b>4.5</b>	164.7	<b>43.0</b>	0.0	75.1/6.6/-12.6/0.0
neos-1445765	3/0/0	34.9	<b>0.7</b>	5.8	0.0	1.4/12.5/-3.4/0.0
neos-1456979	0/0/3	<b>114.7</b>	<b>61.5</b>	822.3	135.4	23.5/-34.3/-43.8/-28.7
neos-1582420	0/2/1	73.2	<b>3.8</b>	215.9	36.2	-5.7/-60.5/-63.2/-74.0
neos-2657525-crna	0/3/0	960.7	<b>0.1</b>	<b>23.5</b>	<b>0.7</b>	5.5/50.0/43.8/65.0
neos-2746589-doon	0/0/3	<b>10.3</b>	<b>367.5</b>	742.4	38.8	70.5/-62.4/-66.6/-19.3
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	1/2/0	<b>2.3</b>	<b>11.7</b>	<b>68.3</b>	<b>18.9</b>	-87.0/-18.8/-20.5/-21.7
neos-3004026-krka	0/0/3	0.0	<b>170.4</b>	1784.6	3.0	0.0/-36.0/-28.0/16.7
neos-3024952-loue	0/1/2	<b>904.4</b>	<b>398.0</b>	1610.8	14.1	-10.1/-79.9/-12.2/49.3
neos-3046615-murg	0/3/0	<b>6091.0</b>	<b>0.1</b>	91.0	59.7	44.1/50.0/3.5/9.0
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/2/1	129.3	<b>111.0</b>	907.4	137.5	-6.5/75.8/17.2/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>40.2</b>	892.1	0.0	0.0/-54.5/15.4/100.0
neos-3402294-bobin	2/1/0	<b>610.0</b>	<b>14.4</b>	18.2	0.0	-29.6/28.4/4.7/0.0
neos-3555904-turama	3/0/0	2.0	73.6	31.2	<b>0.0</b>	0.0/5.9/0.6/100.0
neos-3627168-kasai	3/0/0	<b>1.7</b>	<b>0.2</b>	<b>27.2</b>	<b>0.3</b>	-11.8/-50.0/-25.0/-100.0
neos-3656078-kumeu	0/0/3	28.6	<b>170.5</b>	1166.4	0.0	7.1/-17.7/-10.7/100.0
neos-3754480-nidda	3/0/0	<b>434.5</b>	0.2	67.7	<b>11.0</b>	-15.9/0.0/0.0/19.1
neos-4300652-rahue	0/1/2	<b>210.9</b>	<b>340.2</b>	394.4	0.6	20.7/17.6/-10.1/-50.0
neos-4338804-snowy	0/3/0	<b>14545.0</b>	<b>1.2</b>	<b>133.0</b>	29.5	87.2/-33.3/-24.4/-5.1
neos-4387871-tavua	0/0/3	694.8	24.6	926.9	507.9	8.0/-6.9/-13.5/-15.8
neos-4413714-turia	3/0/0	<b>9.3</b>	73.7	74.2	<b>11.3</b>	78.8/7.8/6.9/13.1
neos-4532248-waihi	0/1/2	949.4	<b>640.6</b>	780.9	250.5	0.0/-23.7/-43.7/-85.6
neos-4647030-tutaki	3/0/0	<b>16.6</b>	<b>25.7</b>	<b>28.0</b>	0.0	24.5/-31.9/-36.8/0.0
neos-4722843-widden	0/3/0	<b>128.7</b>	53.4	94.6	<b>20.6</b>	34.9/3.1/-2.3/19.5

(continued)

Table A.10 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-4738912-atrato	0/3/0	<b>5.7</b>	<i>0.4</i>	<i>21.5</i>	0.0	52.5/-25.0/-42.3/0.0
neos-4763324-toguru	3/0/0	55.6	21.6	24.0	0.0	6.1/-2.3/-1.3/0.0
neos-4954672-berkel	3/0/0	<b>42.4</b>	0.1	<i>38.3</i>	<i>4.9</i>	22.5/0.0/-16.4/-73.5
neos-5049753-cuanza	1/0/2	<b>46.3</b>	<i>1020.5</i>	443.8	76.4	38.8/-24.5/-26.6/-5.8
neos-5052403-cygnnet	3/0/0	<b>0.6</b>	41.1	2.3	0.0	53.8/2.4/0.0/0.0
neos-5093327-huahum	3/0/0	<b>40.6</b>	<b>7.3</b>	<b>79.3</b>	<b>45.6</b>	95.6/45.5/34.3/47.3
neos-5104907-jarama	0/0/2	99.9	1861.5	807.0	242.2	-/-/-/-
neos-5107597-kakapo	0/3/0	<b>34703.3</b>	<i>4.2</i>	<i>306.8</i>	<i>261.6</i>	11.7/-57.1/-59.8/-63.7
neos-5114902-kasavu	1/0/0	55.3	2546.5	114.0	26.0	-/-/-/-
neos-5188808-nattai	3/0/0	4248.9	<b>4.5</b>	25.3	0.0	-5.6/21.1/5.2/0.0
neos-5195221-niemur	3/0/0	760.4	<i>9.0</i>	<i>25.3</i>	0.0	1.0/-17.8/-26.1/0.0
neos-631710	3/0/0	149.4	2.3	1.0	0.0	0.0/8.0/0.0/0.0
neos-662469	0/3/0	<i>286.4</i>	6.2	<i>21.5</i>	<i>1.7</i>	-22.1/3.1/-10.2/-58.8
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	3.27e05	105.1	72.9	20.6	-9.5/-1.7/-4.9/0.5
neos-860300	3/0/0	<i>64.9</i>	<i>0.5</i>	<i>6.0</i>	0.0	-12.2/-20.0/-33.3/0.0
neos-873061	3/0/0	63.4	<i>29.6</i>	34.7	<i>3.0</i>	-3.5/-13.2/-8.6/-46.7
neos-911970	3/0/0	<i>227.7</i>	0.2	53.3	<b>4.0</b>	-42.0/0.0/-6.2/33.3
neos-933966	3/0/0	<b>197.6</b>	1.5	<i>11.7</i>	0.0	11.8/6.3/-19.7/0.0
neos-950242	3/0/0	<b>63.0</b>	<i>7.5</i>	<i>27.8</i>	<i>0.6</i>	50.9/-10.7/-21.6/-33.3
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	1/2/0	<b>1.9</b>	<i>92.0</i>	<i>367.0</i>	<i>22.0</i>	17.4/-78.0/-83.1/-90.5
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<i>2.3</i>	<i>15.5</i>	1216.8	6.9	-39.1/-40.0/-4.0/-62.3
neos17	3/0/0	299.4	0.2	33.3	<i>2.2</i>	-3.1/0.0/-4.8/-27.3
neos20	0/1/2	<i>54.8</i>	<b>7.7</b>	752.4	100.6	-16.6/21.4/36.3/-19.1
neos5	3/0/0	<i>74.8</i>	0.1	<b>3.3</b>	0.0	-44.4/0.0/13.2/0.0
neos7	0/3/0	<b>6.1</b>	<i>0.3</i>	<i>33.9</i>	<i>1.2</i>	44.5/-33.3/-26.3/-100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>24.2</b>	<i>5.2</i>	<i>41.8</i>	<i>1.8</i>	36.8/-17.3/-38.5/-100.0
netdiversion	3/0/0	82.9	<b>62.6</b>	<b>7.1</b>	0.0	4.1/16.4/26.0/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	<i>11.7</i>	<i>22.5</i>	713.5	180.3	-12.8/-39.6/34.7/30.4
nh97t	0/0/3	11.6	<i>49.9</i>	1249.8	340.8	-8.6/-74.3/-12.7/-4.2
noswot	0/3/0	<i>14.2</i>	0.1	<i>54.3</i>	<i>4.7</i>	-32.4/0.0/-36.8/-72.3
ns1116954	0/0/3	0.0	<i>1052.8</i>	1302.9	19.5	0.0/-55.2/-64.1/-83.6
ns1208400	0/2/1	0.0	91.4	675.0	3.9	0.0/-1.4/-41.4/-92.3
ns1644855	3/0/0	<i>1.0</i>	<i>600.8</i>	<i>48.2</i>	<i>7.2</i>	-50.0/-35.0/-28.4/-76.4
ns1760995	3/0/0	<b>12.5</b>	76.3	75.3	<i>3.3</i>	16.1/9.8/6.5/-12.1
ns1830653	0/1/2	<i>529.2</i>	<i>23.3</i>	791.2	71.7	-69.0/-81.1/-92.6/-98.6
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ixp	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.6	0.3	18.6	0.0	-8.3/0.0/2.1/0.0
nursesched-medium-hint03	0/3/0	805.5	<i>18.6</i>	<i>21.4</i>	0.0	-2.4/-25.3/-46.7/0.0
nursesched-sprint02	0/3/0	55.2	<i>2.5</i>	<i>13.9</i>	0.0	0.0/-24.0/-33.1/0.0
nw04	3/0/0	3.9	<i>2.3</i>	<i>9.3</i>	0.0	0.0/-13.0/-14.0/0.0
opm2-z10-s4	3/0/0	94.2	27.2	1.0	0.0	0.0/0.4/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	<i>0.2</i>	<i>43.3</i>	<i>4.2</i>	100.0/-50.0/-16.2/-45.2
p200x1188c	3/0/0	<i>4.4</i>	0.2	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/2	0.0	281.3	985.0	51.7	-/-/-/-
pg	3/0/0	<b>4.4</b>	0.3	55.3	<b>16.9</b>	71.6/0.0/-6.5/12.0
pg5-34	3/0/0	<b>3.6</b>	0.4	53.3	<b>11.0</b>	49.3/0.0/-2.4/19.1
physiciansched3-3	2/1/0	<i>35.4</i>	53.6	<i>68.3</i>	<i>5.7</i>	-75.4/1.7/-32.7/-82.5
physiciansched6-2	0/0/3	<b>2.7</b>	<b>57.3</b>	791.3	80.7	44.9/32.1/-6.5/-56.9
piperout-08	0/0/3	<b>96.3</b>	<b>55.4</b>	1151.5	52.6	75.6/19.9/32.7/-36.7
piperout-27	0/0/3	<b>121.3</b>	63.4	1043.9	28.9	46.9/3.9/12.8/-39.1
pk1	3/0/0	<b>586.7</b>	0.2	62.0	<b>7.8</b>	50.8/0.0/-6.5/12.4
pp08a	3/0/0	<i>77.8</i>	0.1	<i>20.4</i>	0.0	-24.9/0.0/-23.5/0.0
pp08aCUTS	3/0/0	<i>56.0</i>	0.1	<i>21.2</i>	0.0	-37.3/0.0/-43.4/0.0

(continued)

Table A.10 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
proteindesign121hz512p9	0/3/0	2.4	4.9	22.5	<b>0.0</b>	0.0/2.0/7.8/100.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	2/1/0	<b>56.6</b>	8.8	<b>60.9</b>	<b>1.2</b>	14.2/-4.5/-37.9/-100.0
qap10	3/0/0	19.4	13.7	2.0	0.0	0.0/0.0/0.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	258.4	0.5	24.5	<b>0.4</b>	-7.0/0.0/3.2/-100.0
rB10-011001	3/0/0	203.5	0.5	24.5	<b>0.4</b>	0.3/0.0/6.8/-100.0
rB11-010000	3/0/0	291.3	1.4	28.7	<b>1.1</b>	-0.9/-7.1/4.3/-45.5
rB11-110001	3/0/0	<b>119.2</b>	<b>3.8</b>	<b>41.0</b>	<b>0.0</b>	42.6/-31.6/-43.2/100.0
rB12-111111	1/2/0	<b>78.0</b>	<b>18.4</b>	259.9	26.1	13.2/60.3/54.8/-87.7
rC10-001000	3/0/0	<b>131.8</b>	<b>0.3</b>	<b>32.6</b>	0.0	52.1/-33.3/-14.4/0.0
rC10-100001	3/0/0	<b>491.6</b>	<b>6.0</b>	<b>122.3</b>	<b>0.3</b>	-16.9/-18.3/-17.0/62.5
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>212.4</b>	<b>14.0</b>	<b>103.0</b>	<b>1.3</b>	34.0/-63.6/-64.7/-38.5
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>169.1</b>	<b>5.8</b>	<b>132.8</b>	<b>17.4</b>	-10.1/-69.0/-48.6/-79.3
radiationm40-10-02	0/3/0	<b>6813.8</b>	<b>52.0</b>	<b>362.8</b>	<b>29.5</b>	-93.7/-68.8/-60.4/-69.5
rail01	3/0/0	30.1	<b>1107.4</b>	<b>21.9</b>	0.0	2.9/13.5/-45.7/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.1	1.0	0.0	0.0/8.3/0.0/0.0
ran14x18-disj-8	3/0/0	<b>24.8</b>	0.3	21.2	<b>0.0</b>	-33.1/0.0/7.0/100.0
rd-rplusc-21	0/0/3	56.8	<b>43.4</b>	1094.2	495.0	2.2/-16.6/-20.8/-27.2
reblock115	3/0/0	<b>9.0</b>	<b>2.4</b>	<b>89.7</b>	<b>12.8</b>	19.6/-33.3/-38.2/-51.6
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.1	2.0	0.0	0.0/0.0/0.0/0.0
rocl-4-11	0/0/3	<b>60.4</b>	21.6	755.3	107.9	12.7/-1.9/19.0/-3.8
rocll-5-11	1/1/1	85.5	<b>14.7</b>	280.9	91.8	5.4/-42.9/-44.4/-42.7
roi2alpha3n4	3/0/0	<b>38.9</b>	<b>38.6</b>	<b>39.0</b>	<b>2.9</b>	37.7/-13.7/-12.1/-44.8
roi5alpha10n8	3/0/0	60.3	<b>625.3</b>	<b>40.3</b>	<b>3.3</b>	-0.3/-28.6/-28.0/-100.0
roll3000	0/3/0	<b>21.9</b>	1.0	48.9	4.2	16.4/9.1/-1.0/6.7
rout	0/3/0	45.1	0.2	<b>45.0</b>	<b>5.7</b>	8.9/0.0/-21.8/-70.2
s100	3/0/0	<b>2.8</b>	<b>251.0</b>	<b>4.0</b>	0.0	-39.3/17.1/39.4/0.0
s250r10	3/0/0	0.1	53.0	2.0	0.0	0.0/0.7/0.0/0.0
satellites2-40	0/3/0	<b>347.8</b>	<b>73.6</b>	<b>147.0</b>	<b>57.0</b>	-29.4/-39.9/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>92.9</b>	413.8	184.4	-60.0/-75.7/-91.6/-98.5
savsched1	0/3/0	<b>8.8</b>	198.3	13.0	0.0	-10.2/-4.1/-5.4/0.0
sct2	3/0/0	29.7	<b>0.7</b>	<b>31.5</b>	<b>0.8</b>	-1.7/-14.3/-17.1/-25.0
set1ch	3/0/0	<b>59.1</b>	0.1	31.0	1.0	31.0/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	1.4	<b>3.3</b>	<b>9.2</b>	0.0	0.0/-18.2/-17.4/0.0
sing326	3/0/0	<b>15.5</b>	<b>30.5</b>	<b>42.6</b>	<b>4.3</b>	-31.6/-19.0/-20.2/-62.8
sing44	3/0/0	<b>8.5</b>	<b>29.7</b>	<b>44.1</b>	<b>6.1</b>	-12.9/-11.1/-12.7/-37.7
snp-02-004-104	0/3/0	<b>1.2</b>	20.6	34.7	<b>2.3</b>	29.4/-4.4/-3.2/-17.4
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	33.3	<b>2.2</b>	0.0/0.0/-6.0/-40.9
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.2	<b>54.8</b>	<b>8.0</b>	0.0	-0.6/11.8/38.5/0.0
square41	0/3/0	6.7	<b>1438.4</b>	11.0	0.0	0.0/-15.1/-9.1/0.0
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>126.9</b>	118.7	13.5	0.0	25.5/-7.2/0.7/0.0
supportcase12	0/3/0	<b>2.3</b>	<b>16.4</b>	22.6	0.0	-21.7/-11.0/-7.1/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>2336.8</b>	<b>0.3</b>	90.0	59.7	75.1/-33.3/-0.3/5.7
supportcase33	0/3/0	64.4	<b>16.6</b>	<b>193.7</b>	<b>39.3</b>	0.2/-16.9/-37.4/-63.1
supportcase40	3/0/0	<b>25.4</b>	<b>4.7</b>	<b>20.6</b>	0.0	-30.7/-10.6/-19.4/0.0
supportcase42	0/3/0	<b>14.3</b>	<b>5.8</b>	<b>13.9</b>	0.0	41.4/-27.6/-16.5/0.0
supportcase6	3/0/0	<b>0.5</b>	<b>17.2</b>	<b>16.2</b>	0.0	-20.0/-22.7/-25.9/0.0
supportcase7	3/0/0	<b>17.3</b>	9.0	26.0	0.0	-17.3/-7.8/0.0/0.0
swath	0/2/1	<b>203.5</b>	<b>36.8</b>	498.2	186.8	-10.8/-63.3/-62.3/-68.1

(continued)

Table A.10 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
swath1	3/0/0	<b>20.4</b>	<b>1.1</b>	<b>41.6</b>	<b>4.9</b>	66.2/52.2/33.1/68.8
swath3	3/0/0	<b>18.5</b>	<b>1.0</b>	<b>36.7</b>	2.9	44.3/33.3/14.5/9.4
t1717	3/0/0	<b>134.3</b>	115.0	<b>50.3</b>	0.0	25.1/8.9/-13.5/0.0
tbfp-network	3/0/0	<b>39.2</b>	<b>15.3</b>	<b>12.4</b>	0.0	80.4/31.7/11.4/0.0
thor50dday	3/0/0	<b>287.8</b>	<b>8.1</b>	26.5	<b>2.1</b>	-10.4/-11.1/-7.5/-19.0
timtab1	0/3/0	60.8	<b>1.5</b>	<b>136.4</b>	<b>48.7</b>	-8.7/-60.0/-16.6/-42.7
timtab2	0/1/2	72.4	<b>21.0</b>	1014.0	391.1	1.6/-72.4/-22.0/-30.8
tr12-30	3/0/0	<b>48.4</b>	0.2	<b>42.4</b>	<b>6.7</b>	33.6/0.0/-25.2/-76.1
traininstance2	0/1/2	<b>37.5</b>	<b>5.6</b>	595.2	79.9	84.6/-41.1/8.4/-14.1
traininstance6	0/3/0	<b>199.9</b>	<b>0.5</b>	147.0	21.8	56.7/58.3/51.9/48.2
trento1	3/0/0	<b>265.2</b>	8.4	<b>11.7</b>	0.0	-29.4/-4.8/-20.5/0.0
triptim1	0/3/0	0.1	22.2	3.9	0.0	0.0/4.7/2.5/0.0
uccase12	3/0/0	1.9	10.8	16.6	0.0	0.0/-4.6/-6.0/0.0
uccase9	3/0/0	<b>4721.6</b>	<b>32.6</b>	100.2	42.0	15.8/43.7/47.2/42.5
uct-subprob	3/0/0	<b>15.0</b>	<b>0.5</b>	<b>10.0</b>	0.0	-17.3/16.7/-23.0/0.0
unitcal-7	0/0/3	<b>20.0</b>	127.5	891.2	55.0	25.4/7.4/10.1/62.3
var-smallerny-m6j6	3/0/0	<b>14.4</b>	24.7	70.9	<b>11.3</b>	94.4/-2.8/-4.8/-10.6
vpm2	3/0/0	43.0	0.1	<b>28.6</b>	<b>0.3</b>	4.4/0.0/-28.7/-100.0
wachplan	0/3/0	0.0	3.3	<b>37.0</b>	0.0	0.0/-9.1/-28.4/0.0
Geom. means		(271 instances)	(225 instances)			
FP		45.7	5.4	15.2	1.1	
FP+(10,l,g)		<b>41.0</b>	<b>6.1</b>	<b>17.2</b>	<b>1.4</b>	

Table A.11.: Performance of FP+(2,l,h)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	3/0/0	<b>6.6</b>	<b>3.5</b>	<b>53.8</b>	<b>0.3</b>	45.5/71.3/66.3/75.0
30n20b8	0/3/0	<b>410.7</b>	<b>10.2</b>	<b>348.9</b>	<b>90.0</b>	11.1/-44.1/-52.1/-67.9
50v-10	0/3/0	138.2	0.3	21.7	0.3	-9.8/0.0/5.7/0.0
CMS750-4	3/0/0	<b>73.3</b>	<b>5.7</b>	<b>94.7</b>	<b>20.0</b>	-27.7/-28.1/-31.3/-40.0
a1c1s1	3/0/0	<b>33.9</b>	<b>0.5</b>	31.3	1.3	35.8/-20.0/0.0/0.0
academicimetablesmall	0/0/3	inf	540.8	799.7	0.6	-/-/-/-
aflow30a	3/0/0	<b>109.7</b>	0.1	31.3	<b>1.3</b>	16.6/0.0/6.6/35.0
aflow40b	3/0/0	<b>142.6</b>	0.3	31.3	<b>1.1</b>	31.2/0.0/2.2/26.7
air04	3/0/0	<b>1.0</b>	<b>2.9</b>	<b>9.6</b>	0.0	-90.0/-10.3/-31.2/0.0
air05	3/0/0	<b>2.4</b>	<b>1.1</b>	<b>7.3</b>	0.0	41.5/-27.3/-45.2/0.0
app1-1	3/0/0	<b>42.0</b>	<b>0.6</b>	35.5	4.1	-92.6/-16.7/-2.5/-2.4
app1-2	3/0/0	43.1	<b>11.9</b>	<b>58.0</b>	16.9	1.8/-10.1/-10.7/-9.5
arki001	0/1/2	2.8	<b>16.0</b>	671.3	145.2	3.4/22.7/16.5/22.1
assign1-5-8	3/0/0	<b>4.3</b>	0.1	24.1	0.0	-55.8/0.0/-7.5/0.0
atlanta-ip	3/0/0	<b>10.5</b>	15.4	<b>18.3</b>	<b>0.0</b>	41.7/8.9/29.1/100.0
b1c1s1	3/0/0	<b>220.3</b>	0.5	33.7	3.6	-26.8/0.0/0.0/0.0
bab2	1/1/1	<b>13.9</b>	<b>392.1</b>	240.7	25.9	45.5/-19.9/-28.1/-9.3
bab6	1/0/2	<b>13.6</b>	<b>280.7</b>	349.5	79.4	42.6/-62.8/-74.9/-80.7
beasleyC3	3/0/0	11.1	0.2	35.7	<b>5.6</b>	4.3/0.0/-2.0/-14.3
binkar10-1	3/0/0	3.9	0.1	<b>7.7</b>	0.0	2.5/0.0/51.0/0.0
blp-ar98	3/0/0	72.8	<b>2.4</b>	<b>19.8</b>	0.0	-2.1/-16.7/-14.6/0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/2	0.0	192.7	735.8	0.0	-/-/-/-
bppc4-08	3/0/0	<b>280.1</b>	1.1	62.0	<b>6.3</b>	-81.6/8.3/0.5/32.3
brazil3	0/3/0	<b>378.2</b>	<b>17.4</b>	21.3	0.0	40.4/17.5/0.5/0.0
buildingenergy	0/3/0	1.1	<b>590.5</b>	11.0	0.0	0.0/15.2/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	inf	2.8	40.3	10.3	-100.0/-3.6/-0.7/-2.9
chromaticindex1024-7	3/0/0	0.0	54.6	<b>2.3</b>	0.0	0.0/0.4/23.3/0.0
chromaticindex512-7	3/0/0	0.0	45.2	2.0	0.0	0.0/-0.4/0.0/0.0
cmflsp50-24-8-8	1/1/1	<b>17.3</b>	<b>37.3</b>	256.9	71.8	11.3/77.7/75.5/75.6

(continued)

Table A.11 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
co-100	3/0/0	313.2	6.4	16.8	0.0	-3.3/-4.7/-7.1/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	<b>3921.1</b>	6.7	<b>28.0</b>	0.0	-12.6/-7.5/-14.3/0.0
comp21-2idx	0/3/0	413.1	4.5	26.7	0.0	3.2/2.2/-6.0/0.0
cost266-UUE	3/0/0	32.7	<b>0.5</b>	<b>29.5</b>	<b>0.6</b>	6.8/-20.0/-20.3/-50.0
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/2/1	<b>80.3</b>	<b>8.6</b>	829.1	177.4	-14.1/-29.1/-53.9/-72.2
csched008	1/2/0	9.4	<b>1.5</b>	159.6	<b>35.7</b>	4.1/11.8/-4.8/-32.8
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	17.8	<b>18.0</b>	0.0	0.0/4.8/-10.0/0.0
dano3-5	3/0/0	<b>0.1</b>	<b>35.4</b>	31.5	<b>1.1</b>	50.0/19.5/-4.4/-18.2
dano3mip	3/0/0	<b>10.6</b>	<b>170.4</b>	70.7	17.6	38.4/39.2/-0.1/3.8
danoint	2/1/0	<b>168.1</b>	<b>2.6</b>	<b>91.9</b>	<b>30.0</b>	74.2/35.0/17.6/27.2
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	5.6	<b>0.4</b>	13.3	0.0	0.0/-25.0/-2.3/0.0
drayage-25-23	3/0/0	<b>14.5</b>	<b>0.6</b>	<b>21.2</b>	0.0	-29.7/-33.3/-22.6/0.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0
dws008-01	0/0/3	<b>77.9</b>	72.8	832.1	252.6	18.8/2.4/-1.5/-6.7
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0	0.0/0.0/0.0/0.0
enlight-hard	0/0/2	0.0	3.2	740.3	235.9	-/-/-/-
exp-1-500-5-5	3/0/0	<b>51.8</b>	0.1	25.7	0.0	31.3/0.0/4.5/0.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>530.7</b>	0.4	<b>26.7</b>	<b>0.9</b>	41.5/0.0/-24.0/-100.0
fhnw-binpack4-48	0/0/1	0.0	55.1	1528.0	222.0	-/-/-/-
fiball	0/3/0	<b>14.4</b>	7.2	56.2	<b>5.2</b>	16.3/-2.8/-0.4/-11.5
fiber	3/0/0	153.6	0.1	15.3	0.0	0.0/0.0/-2.6/0.0
fixnet6	3/0/0	<b>57.7</b>	0.1	31.0	1.0	-26.2/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>13.5</b>	0.1	<b>4.5</b>	0.0	-22.2/0.0/-35.6/0.0
germanrr	0/3/0	<b>5.9</b>	<b>18.0</b>	<b>90.3</b>	<b>18.9</b>	-30.5/-35.0/-43.7/-68.8
gesa2	0/3/0	2.4	0.2	20.4	0.0	0.0/0.0/0.0/0.0
gesa2-o	0/3/0	19.4	0.2	35.2	<b>1.3</b>	3.0/0.0/1.1/13.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	2/1/0	<b>796.0</b>	<b>0.4</b>	<b>131.3</b>	<b>45.0</b>	-14.4/-25.0/-20.6/-28.4
gmu-35-40	3/0/0	6.5	0.1	14.0	0.0	0.0/0.0/0.0/0.0
gmu-35-50	3/0/0	<b>8.2</b>	0.3	<b>36.2</b>	<b>1.5</b>	32.8/0.0/-13.3/-33.3
graph20-20-1rand	3/0/0	<b>30.2</b>	<b>4.7</b>	<b>39.9</b>	<b>1.0</b>	-53.6/-12.8/-21.6/-60.0
graphdraw-domain	0/3/0	<b>99.8</b>	<b>0.4</b>	<b>85.0</b>	<b>20.0</b>	-71.1/-25.0/-28.6/-48.0
h80x6320d	3/0/0	22.0	1.2	32.0	1.9	0.0/0.0/0.0/0.0
harp2	3/0/0	12.1	0.1	12.7	0.0	2.4/0.0/0.0/0.0
highschool1-aigio	0/3/0	inf	733.2	<b>24.2</b>	0.0	0.0/-6.1/-36.8/0.0
hypothyroid-k1	3/0/0	0.0	4.6	1.0	0.0	0.0/4.2/0.0/0.0
ic97p	0/0/3	<b>13.3</b>	<b>4.3</b>	767.2	221.3	13.6/15.7/13.5/-7.2
ic97t	0/1/2	<b>14.8</b>	<b>2.7</b>	892.8	258.7	-16.2/30.8/29.5/16.9
icir97p	0/0/3	20.7	21.3	1010.7	145.8	9.6/1.4/11.3/32.4
icir97t	0/3/0	14.4	4.7	216.1	122.6	8.3/-6.4/-2.6/4.8
irish-electricity	3/0/0	5.7	20.2	<b>19.3</b>	<b>0.0</b>	5.0/-4.0/20.2/100.0
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>19.6</b>	6.4	23.0	0.0	45.6/0.0/-4.3/0.0
k1mushroom	3/0/0	18.2	40.2	1.0	0.0	0.0/-1.0/0.0/0.0
lectsched-5-obj	0/0/3	2282.3	87.4	908.0	6.4	-1.6/-3.9/0.1/8.6
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	674.7	1.2	90.3	57.3	0.0/-8.3/-0.3/-1.2
lotsize	0/0/3	<b>542.7</b>	<b>7.0</b>	735.6	355.9	-87.0/-92.9/-93.9/-97.0
mad	3/0/0	<b>7880.9</b>	0.1	16.3	0.0	36.2/0.0/-9.8/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>90.6</b>	45.5	<b>59.1</b>	<b>13.2</b>	-50.7/8.8/-39.4/-75.8
map16715-04	3/0/0	90.8	59.7	51.0	10.0	-1.8/-4.7/-9.2/-9.0

(continued)

Table A.11 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>425.6</b>	0.2	90.0	<b>9.5</b>	10.6/0.0/0.0/34.9
mas76	0/3/0	106.5	0.2	90.0	<b>10.0</b>	-0.7/0.0/0.8/53.5
mc11	3/0/0	105.9	0.4	43.0	12.6	2.1/0.0/-0.9/-2.4
mcsched	3/0/0	<b>9.8</b>	<b>0.6</b>	4.0	0.0	24.0/-16.7/-10.0/0.0
mik-250-20-75-4	0/3/0	<b>53.5</b>	0.2	<b>21.0</b>	<b>2.0</b>	12.4/0.0/45.2/55.6
milo-v12-6-r2-40-1	3/0/0	<b>124.1</b>	0.9	42.3	12.3	17.4/0.0/-0.7/-2.4
misc07	3/0/0	<b>48.9</b>	0.1	<b>17.5</b>	0.0	-41.5/0.0/12.9/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>8.2</b>	0.3	19.6	0.0	41.4/0.0/0.0/0.0
modglob	3/0/0	108.7	0.1	31.3	1.3	-2.6/0.0/0.0/0.0
momentum1	0/1/2	209.2	<b>98.1</b>	1277.7	689.0	-7.6/-59.7/-56.3/-48.8
msc98-ip	3/0/0	<b>11.4</b>	<b>5.6</b>	27.7	0.6	26.5/11.1/9.8/0.0
mushroom-best	0/3/0	<b>1.12e07</b>	14.9	43.3	<b>1.5</b>	-18.1/-8.7/-7.6/11.8
mzzv11	0/3/0	18.2	3.8	20.0	0.0	9.5/9.5/-3.5/0.0
mzzv42z	0/3/0	<b>37.7</b>	<b>3.9</b>	<b>20.6</b>	<b>0.0</b>	-17.8/20.4/13.4/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	9.5	<b>0.4</b>	<b>27.2</b>	<b>0.3</b>	-1.1/-25.0/-25.0/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>6.4</b>	5.0	29.3	<b>0.4</b>	-85.9/-2.0/-9.9/33.3
neos-1171737	3/0/0	<b>4.5</b>	1.5	<b>25.7</b>	0.6	-13.3/6.3/13.2/0.0
neos-1354092	0/3/0	<b>8.6</b>	159.9	37.2	0.0	52.5/9.3/1.1/0.0
neos-1445765	3/0/0	<b>30.4</b>	<b>0.7</b>	6.1	0.0	14.1/12.5/-8.2/0.0
neos-1456979	0/2/1	<b>86.4</b>	<b>11.8</b>	142.2	17.4	42.4/70.8/69.2/82.0
neos-1582420	0/3/0	<b>90.2</b>	<b>3.6</b>	<b>202.7</b>	<b>24.0</b>	-23.5/-58.3/-60.8/-60.8
neos-2657525-crna	0/3/0	1016.4	<b>0.1</b>	<b>37.2</b>	<b>1.7</b>	0.0/50.0/11.0/15.0
neos-2746589-doon	0/0/3	<b>7.1</b>	<b>922.9</b>	699.0	24.6	79.7/-85.0/-64.5/21.4
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	2/1/0	<b>0.2</b>	10.1	59.0	14.8	33.3/-5.9/-8.0/0.0
neos-3004026-krka	0/0/3	0.0	<b>127.7</b>	1432.2	3.0	0.0/-14.6/-10.2/16.7
neos-3024952-loue	0/0/3	872.7	<b>133.4</b>	1743.9	44.3	-6.8/-40.1/-18.9/-37.2
neos-3046615-murg	0/3/0	10663.7	0.2	100.8	68.9	2.2/0.0/-6.4/-4.8
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	<b>134.8</b>	<b>280.8</b>	1174.1	6.7	-10.3/38.7/-6.6/-100.0
neos-3381206-awhea	0/0/3	4.9	18.9	953.2	0.6	0.0/-3.2/9.6/45.5
neos-3402294-bobin	2/1/0	<b>663.4</b>	<b>24.1</b>	<b>24.9</b>	<b>0.3</b>	-35.3/-16.6/-23.3/-100.0
neos-3555904-turama	3/0/0	<b>4.3</b>	78.9	<b>35.9</b>	<b>0.6</b>	-53.5/-0.9/-12.5/-33.3
neos-3627168-kasai	3/0/0	1.4	0.1	20.4	0.0	6.7/0.0/0.0/0.0
neos-3656078-kumeu	0/0/3	31.8	<b>125.4</b>	1165.0	2.1	-3.1/10.6/-10.6/-57.1
neos-3754480-nidda	3/0/0	<b>9372.6</b>	0.2	68.6	<b>11.9</b>	-96.1/0.0/-1.3/12.5
neos-4300652-rahue	0/0/3	253.6	<b>774.9</b>	743.8	0.0	4.6/-46.7/-52.3/100.0
neos-4338804-snowy	0/3/0	<b>40074.9</b>	<b>1.0</b>	<b>121.8</b>	<b>32.0</b>	64.8/-20.0/-17.5/-12.5
neos-4387871-tavua	0/0/3	<b>918.1</b>	<b>27.5</b>	1078.4	532.9	-17.8/-16.7/-25.6/-19.8
neos-4413714-turia	3/0/0	<b>32.1</b>	77.9	78.4	<b>10.3</b>	26.9/2.5/1.6/20.8
neos-4532248-waihi	0/0/3	949.4	<b>761.0</b>	940.3	205.2	0.0/-35.7/-53.2/-82.4
neos-4647030-tutaki	3/0/0	<b>33.2</b>	<b>24.1</b>	<b>25.7</b>	0.0	-33.7/-27.4/-31.1/0.0
neos-4722843-widden	0/3/0	<b>53.1</b>	<b>27.5</b>	<b>50.7</b>	<b>6.7</b>	73.1/50.1/45.1/73.8
neos-4738912-atrato	0/3/0	11.4	<b>0.4</b>	<b>21.5</b>	0.0	5.0/-25.0/-42.3/0.0
neos-4763324-toguru	3/0/0	55.6	21.0	23.3	0.0	6.1/0.5/1.7/0.0
neos-4954672-berkel	3/0/0	<b>47.1</b>	0.1	<b>38.0</b>	<b>5.2</b>	13.9/0.0/-15.8/-75.0
neos-5049753-cuanza	0/2/1	<b>60.3</b>	766.0	343.4	91.2	20.2/0.6/-5.2/-21.1
neos-5052403-cygnat	3/0/0	<b>0.6</b>	41.4	2.3	0.0	53.8/1.7/0.0/0.0
neos-5093327-huahum	3/0/0	<b>108.2</b>	<b>8.1</b>	<b>86.0</b>	<b>51.0</b>	88.2/39.6/28.7/41.1
neos-5104907-jarama	0/0/1	120.5	2494.6	811.0	53.0	-/-/-/-
neos-5107597-kakapo	2/1/0	<b>9835.8</b>	<b>3.2</b>	<b>229.9</b>	<b>190.2</b>	75.0/-43.8/-46.4/-50.1
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	4318.9	<b>4.6</b>	24.9	0.0	-7.1/19.3/6.7/0.0
neos-5195221-niemur	3/0/0	<b>918.8</b>	<b>5.6</b>	<b>11.9</b>	0.0	-16.4/24.3/36.4/0.0

(continued)

Table A.11 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	<b>322.7</b>	<b>4.5</b>	<b>11.3</b>	<b>0.0</b>	-30.9/29.7/41.5/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>4.94e05</b>	104.5	72.7	20.3	-40.1/-1.1/-4.7/1.9
neos-860300	3/0/0	<b>49.1</b>	<b>0.6</b>	<b>6.6</b>	0.0	13.9/-33.3/-39.4/0.0
neos-873061	3/0/0	<b>53.3</b>	26.6	31.7	1.6	12.9/-3.4/0.0/0.0
neos-911970	3/0/0	<b>181.3</b>	0.2	53.0	<b>4.8</b>	-27.2/0.0/-5.7/20.0
neos-933966	3/0/0	<b>196.9</b>	<b>1.4</b>	<b>10.5</b>	0.0	12.1/12.5/-10.5/0.0
neos-950242	2/1/0	<b>80.0</b>	<b>13.7</b>	<b>38.4</b>	<b>2.3</b>	37.6/-51.1/-43.2/-82.6
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	1/2/0	<b>1.7</b>	<b>42.5</b>	<b>171.9</b>	<b>5.1</b>	26.1/-52.5/-64.0/-58.8
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	1.4	<b>7.5</b>	858.2	9.7	0.0/19.4/26.6/-73.2
neos17	3/0/0	306.9	0.2	31.7	1.6	-5.4/0.0/0.0/0.0
neos20	0/0/3	<b>57.0</b>	9.3	1066.5	88.1	-19.8/5.1/9.7/-7.6
neos5	3/0/0	<b>78.7</b>	0.1	<b>3.3</b>	0.0	-47.1/0.0/13.2/0.0
neos7	0/3/0	<b>8.8</b>	0.2	27.3	0.0	20.0/0.0/-8.4/0.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>30.5</b>	<b>3.8</b>	<b>22.6</b>	0.0	20.4/11.6/12.1/0.0
netdiversion	3/0/0	84.9	<b>66.1</b>	<b>8.5</b>	0.0	1.7/11.7/11.5/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	<b>8.7</b>	<b>11.3</b>	796.4	214.0	14.7/16.9/27.1/17.4
nh97t	0/0/3	10.6	<b>17.2</b>	1254.5	352.5	0.0/-25.6/-13.0/-7.3
noswot	0/3/0	<b>8.1</b>	0.1	34.2	1.2	15.6/0.0/0.3/7.7
ns1116954	1/0/2	0.0	446.8	493.6	4.1	0.0/5.3/-5.3/-22.0
ns1208400	0/3/0	0.0	88.0	<b>556.0</b>	<b>1.9</b>	0.0/2.3/-28.9/-84.2
ns1644855	3/0/0	<b>0.3</b>	<b>277.1</b>	32.3	<b>1.0</b>	40.0/29.1/6.4/41.2
ns1760995	3/0/0	<b>18.4</b>	76.6	76.0	<b>1.3</b>	-19.0/9.5/5.6/55.2
ns1830653	0/3/0	<b>525.9</b>	<b>13.9</b>	<b>398.1</b>	<b>17.6</b>	-68.8/-68.3/-85.2/-94.3
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ipx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.3	0.3	19.3	0.0	0.0/0.0/-1.6/0.0
nursesched-medium-hint03	0/3/0	809.8	<b>18.2</b>	<b>20.4</b>	0.0	-2.9/-23.6/-44.1/0.0
nursesched-sprint02	0/3/0	52.1	<b>2.6</b>	<b>13.9</b>	0.0	5.6/-26.9/-33.1/0.0
nw04	3/0/0	3.9	2.1	8.3	0.0	0.0/-4.8/-3.6/0.0
opm2-z10-s4	3/0/0	94.2	27.2	1.0	0.0	0.0/0.4/0.0/0.0
opt1217	3/0/0	<b>4.7</b>	<b>0.2</b>	<b>45.5</b>	<b>6.0</b>	39.7/-50.0/-20.2/-61.7
p200x1188c	3/0/0	3.9	0.2	31.0	1.0	0.0/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/-
pg	3/0/0	<b>10.7</b>	0.3	53.6	<b>16.6</b>	31.0/0.0/-3.5/13.5
pg5-34	3/0/0	<b>5.6</b>	0.4	52.0	<b>11.0</b>	21.1/0.0/0.0/19.1
physiciansched3-3	3/0/0	<b>4.8</b>	49.7	<b>28.5</b>	<b>0.4</b>	44.8/8.8/38.0/60.0
physiciansched6-2	0/0/3	<b>4.4</b>	<b>69.7</b>	818.1	44.4	10.2/17.4/-9.5/-21.6
piperout-08	0/0/3	<b>189.2</b>	<b>50.6</b>	1234.5	43.7	52.1/26.9/27.8/-23.8
piperout-27	0/0/3	<b>50.9</b>	66.9	1209.7	37.6	77.7/-1.3/-1.1/-53.2
pk1	3/0/0	1207.0	0.2	59.0	<b>7.9</b>	-1.3/0.0/-1.7/11.2
pp08a	3/0/0	<b>42.4</b>	0.1	17.3	0.0	27.4/0.0/-9.8/0.0
pp08aCUTS	3/0/0	<b>44.6</b>	0.1	<b>18.7</b>	0.0	-21.3/0.0/-35.8/0.0
proteindesign121hz512p9	0/3/0	2.4	5.1	24.4	0.3	0.0/-2.0/0.0/0.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	3/0/0	66.3	<b>7.2</b>	34.1	<b>0.6</b>	-0.5/14.3/9.8/-100.0
qap10	3/0/0	19.4	13.8	2.0	0.0	0.0/-0.7/0.0/0.0
qiu	3/0/0	1563.9	0.1	<b>3.8</b>	0.0	0.0/0.0/-13.2/0.0
rB10-011000	3/0/0	<b>328.6</b>	0.5	<b>22.0</b>	0.0	-26.9/0.0/13.0/0.0
rB10-011001	3/0/0	<b>268.0</b>	0.5	<b>23.5</b>	<b>0.6</b>	-23.8/0.0/10.6/-100.0
rB11-010000	3/0/0	<b>335.4</b>	1.2	<b>24.0</b>	<b>0.3</b>	-13.9/7.7/20.0/50.0
rB11-110001	3/0/0	<b>163.8</b>	<b>3.3</b>	<b>33.7</b>	<b>1.0</b>	21.1/-21.2/-30.9/-70.0
rB12-111111	0/2/1	83.5	<b>56.4</b>	824.1	23.2	7.1/-17.7/-30.3/-86.2
rC10-001000	3/0/0	<b>221.2</b>	<b>0.3</b>	30.2	<b>0.3</b>	19.6/-33.3/-7.6/-100.0

(continued)



Table A.11 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
rC10-100001	3/0/0	431.6	4.8	99.8	<b>0.6</b>	-5.4/2.0/1.7/25.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>270.9</b>	<b>7.6</b>	<b>57.3</b>	<b>1.6</b>	15.8/-32.9/-36.5/-50.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>266.1</b>	<b>2.8</b>	<b>116.8</b>	<b>17.6</b>	-42.8/-35.7/-41.5/-79.5
radiationm40-10-02	0/3/0	<b>1128.6</b>	<b>24.7</b>	<b>230.6</b>	<b>18.4</b>	-61.8/-34.4/-37.6/-51.1
rail01	3/0/0	<b>35.4</b>	1190.5	<b>14.9</b>	0.0	-12.4/7.0/-20.1/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.1	1.0	0.0	0.0/8.3/0.0/0.0
ran14x18-disj-8	3/0/0	<b>25.4</b>	0.3	23.3	<b>0.6</b>	-34.6/0.0/-2.1/-50.0
rd-rplusc-21	0/0/3	56.0	39.3	882.7	362.6	3.6/-7.9/-1.8/-0.6
reblock115	3/0/0	<b>9.2</b>	<b>1.8</b>	<b>67.0</b>	<b>9.8</b>	17.9/-11.1/-17.3/-36.7
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.1	2.0	0.0	0.0/0.0/0.0/0.0
rocl-4-11	0/0/3	<b>51.7</b>	<b>18.4</b>	817.9	91.5	25.3/13.2/12.3/11.8
rocll-5-11	0/3/0	<b>68.1</b>	<b>23.9</b>	<b>464.8</b>	<b>153.2</b>	24.7/-64.9/-66.4/-65.7
roi2alpha3n4	3/0/0	<b>36.7</b>	<b>37.9</b>	37.2	<b>2.2</b>	41.2/-12.1/-7.8/-27.3
roi5alpha10n8	3/0/0	56.8	471.6	31.8	<b>0.6</b>	5.5/-5.3/-8.8/-100.0
roll3000	0/3/0	27.4	1.1	52.5	<b>6.3</b>	-4.4/0.0/-7.8/-28.6
rout	0/3/0	<b>42.1</b>	0.2	<b>46.7</b>	<b>6.1</b>	14.9/0.0/-24.6/-72.1
s100	3/0/0	<b>2.8</b>	299.2	7.0	0.0	-39.3/1.2/-5.7/0.0
s250r10	3/0/0	0.1	53.2	2.0	0.0	0.0/0.4/0.0/0.0
satellites2-40	0/3/0	<b>287.5</b>	<b>71.7</b>	<b>147.0</b>	<b>57.0</b>	-14.6/-38.4/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>95.4</b>	410.2	182.9	-60.0/-76.3/-91.5/-98.5
savshed1	0/3/0	<b>7.0</b>	199.9	13.0	0.0	11.4/-4.9/-5.4/0.0
sct2	3/0/0	<b>23.2</b>	0.6	26.9	<b>0.0</b>	20.5/0.0/-3.0/100.0
set1ch	3/0/0	<b>61.9</b>	0.1	31.0	1.0	27.7/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	1.4	3.0	<b>8.6</b>	0.0	0.0/-10.0/-11.6/0.0
sing326	3/0/0	<b>9.3</b>	<b>27.6</b>	37.3	<b>2.9</b>	12.3/-10.5/-8.8/-44.8
sing44	3/0/0	7.3	26.0	37.6	<b>2.7</b>	1.4/1.5/2.3/28.9
snp-02-004-104	0/3/0	1.7	19.7	33.6	1.9	0.0/0.0/0.0/0.0
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.3	1.3	0.0/0.0/0.0/0.0
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	100.2	62.3	13.0	0.0	-1.6/-0.3/0.0/0.0
square41	0/3/0	6.7	<b>1526.1</b>	<b>12.4</b>	0.0	0.0/-20.0/-19.4/0.0
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>153.2</b>	108.1	<b>11.6</b>	0.0	10.0/1.8/14.7/0.0
supportcase12	0/3/0	<b>2.1</b>	13.6	21.6	0.0	-14.3/6.8/-2.8/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>5459.8</b>	0.2	90.0	59.7	41.8/0.0/-0.3/5.7
supportcase33	0/3/0	<b>57.1</b>	<b>19.5</b>	<b>194.9</b>	<b>43.2</b>	11.5/-29.2/-37.8/-66.4
supportcase40	3/0/0	<b>24.3</b>	4.4	<b>18.5</b>	0.0	-27.6/-4.5/-10.3/0.0
supportcase42	0/3/0	<b>14.3</b>	<b>4.8</b>	<b>13.7</b>	0.0	41.4/-12.5/-15.3/0.0
supportcase6	3/0/0	<b>2.6</b>	13.2	12.7	0.0	-84.6/0.8/-5.5/0.0
supportcase7	3/0/0	15.1	8.6	26.0	0.0	-5.3/-3.5/0.0/0.0
swath	0/3/0	192.9	<b>21.5</b>	<b>274.2</b>	<b>92.4</b>	-5.9/-37.2/-31.5/-35.5
swath1	3/0/0	<b>18.1</b>	<b>1.1</b>	<b>41.3</b>	<b>4.4</b>	70.0/52.2/33.6/72.0
swath3	3/0/0	<b>19.2</b>	<b>1.2</b>	42.4	<b>5.4</b>	42.2/20.0/1.2/-40.7
t1717	3/0/0	179.1	<b>147.8</b>	<b>63.2</b>	0.0	0.1/-14.5/-31.2/0.0
tbfp-network	3/0/0	<b>173.7</b>	<b>25.4</b>	14.8	0.0	12.9/-11.8/-5.4/0.0
thor50dday	3/0/0	257.8	7.3	24.5	1.7	0.0/-1.4/0.0/0.0
timtab1	0/3/0	57.9	<b>0.4</b>	<b>71.8</b>	<b>20.7</b>	-4.1/33.3/36.9/25.8
timtab2	0/2/1	73.6	<b>5.2</b>	511.7	181.6	0.0/10.3/35.3/32.9
tr12-30	3/0/0	69.2	0.2	31.3	<b>1.3</b>	5.1/0.0/1.3/18.8
traininstance2	0/1/2	254.2	<b>5.1</b>	940.4	108.6	-4.2/-35.3/-30.9/-36.8
traininstance6	0/3/0	<b>115.1</b>	<b>0.4</b>	132.7	15.2	75.1/66.7/56.6/63.9
trento1	3/0/0	<b>283.3</b>	8.2	<b>10.9</b>	0.0	-34.0/-2.4/-14.7/0.0

(continued)

Table A.11 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
triptim1	0/3/0	0.1	22.7	4.2	0.0	0.0/2.6/-4.8/0.0
uccase12	3/0/0	<b>2.7</b>	10.5	16.2	0.0	-29.6/-1.9/-3.7/0.0
uccase9	3/0/0	<b>4856.6</b>	<b>33.4</b>	103.0	40.4	13.4/42.3/45.7/44.7
uct-subprob	3/0/0	<b>15.4</b>	<b>0.5</b>	<b>9.7</b>	0.0	-19.5/16.7/-20.6/0.0
unitcal-7	0/1/2	<b>39.7</b>	134.5	1008.4	186.5	-32.5/2.3/-1.7/-21.8
var-smallemergy-m6j6	3/0/0	<b>45.8</b>	24.1	68.3	9.6	82.1/-0.4/-1.2/5.0
vpm2	3/0/0	43.8	0.1	<b>27.2</b>	<b>0.3</b>	2.7/0.0/-25.0/-100.0
wachplan	0/3/0	0.0	<b>2.5</b>	24.5	0.0	0.0/16.7/7.5/0.0
Geom. means		(271 instances)	(231 instances)			
FP		45.7	5.4	16.2	1.2	
FP+(2,l,h)		<b>45.3</b>	<b>5.6</b>	<b>17.5</b>	<b>1.3</b>	

Table A.12.: Performance of FP+(3,l,h)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	3/0/0	<b>1.6</b>	<b>1.4</b>	<b>17.3</b>	<b>0.3</b>	86.8/88.5/89.2/75.0
30n20b8	0/1/2	<b>612.9</b>	<b>17.0</b>	591.3	118.8	-24.6/-66.5/-71.8/-75.7
50v-10	0/3/0	128.2	0.3	22.0	0.3	-2.7/0.0/4.3/0.0
CMS750-4	3/0/0	<b>62.3</b>	<b>6.3</b>	<b>105.6</b>	12.7	-14.9/-34.9/-38.4/-5.5
a1c1s1	3/0/0	<b>26.0</b>	<b>0.5</b>	31.7	<b>1.6</b>	50.8/-20.0/-1.3/-18.8
academictimetablesmall	0/0/1	inf	435.3	729.0	0.0	-/-/-/-
aflow30a	3/0/0	135.4	0.1	34.3	<b>2.3</b>	-2.8/0.0/-2.3/-13.0
aflow40b	3/0/0	207.5	<b>0.4</b>	<b>37.6</b>	<b>4.9</b>	-0.1/-25.0/-14.9/-69.4
air04	3/0/0	<b>0.9</b>	<b>3.2</b>	<b>11.8</b>	0.0	-88.9/-18.8/-44.1/0.0
air05	3/0/0	<b>3.1</b>	<b>1.5</b>	<b>16.7</b>	0.0	24.4/-46.7/-76.0/0.0
app1-1	3/0/0	<b>33.3</b>	<b>0.6</b>	<b>39.4</b>	<b>5.9</b>	-90.7/-16.7/-12.2/-32.2
app1-2	0/3/0	43.9	<b>27.7</b>	<b>147.4</b>	<b>72.3</b>	0.0/-61.4/-64.9/-78.8
arki001	0/2/1	3.2	19.1	786.7	191.9	-9.4/7.7/2.2/-2.9
assign1-5-8	3/0/0	<b>1.5</b>	0.1	22.6	0.0	21.1/0.0/-1.3/0.0
atlanta-ip	3/0/0	<b>15.2</b>	15.7	<b>22.4</b>	<b>0.0</b>	15.6/7.1/13.2/100.0
b1c1s1	3/0/0	159.7	<b>0.6</b>	36.0	<b>4.3</b>	1.0/-16.7/-6.4/-16.3
bab2	1/0/2	<b>15.1</b>	<b>540.6</b>	397.6	65.1	40.8/-41.9/-56.5/-63.9
bab6	1/1/1	<b>16.9</b>	<b>209.8</b>	258.8	31.5	28.7/-50.2/-66.1/-51.4
beasleyC3	3/0/0	11.0	0.2	35.7	<b>5.6</b>	5.2/0.0/-2.0/-14.3
binkar10-1	3/0/0	3.9	0.1	<b>7.7</b>	0.0	2.5/0.0/51.0/0.0
blp-ar98	3/0/0	72.5	2.1	17.2	0.0	-1.7/-4.8/-1.7/0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/1	0.0	251.7	1170.0	0.0	-/-/-/-
bppc4-08	3/0/0	<b>41.2</b>	1.1	61.3	<b>7.1</b>	20.2/8.3/1.6/23.7
brazil3	0/3/0	<b>204.1</b>	<b>17.1</b>	22.6	0.0	67.8/19.0/-5.3/0.0
buildingenergy	0/3/0	1.1	629.4	11.0	0.0	0.0/9.7/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.7	40.7	10.7	0.0/0.0/-1.7/-6.5
chromaticindex1024-7	3/0/0	0.0	54.4	<b>2.3</b>	0.0	0.0/0.7/23.3/0.0
chromaticindex512-7	3/0/0	0.0	45.1	2.0	0.0	0.0/-0.2/0.0/0.0
cmflsp50-24-8-8	1/2/0	19.2	<b>43.3</b>	333.0	106.2	1.5/74.1/68.3/64.0
co-100	3/0/0	302.4	6.3	15.9	0.0	0.1/-3.2/-1.9/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	3664.4	6.0	24.0	0.0	-6.5/3.2/0.0/0.0
comp21-2idx	0/3/0	435.5	4.8	27.5	<b>0.3</b>	-2.0/-4.2/-8.7/-100.0
cost266-UUE	3/0/0	36.5	<b>0.5</b>	<b>29.9</b>	<b>0.6</b>	-3.8/-20.0/-21.4/-50.0
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/1/2	<b>52.8</b>	<b>10.4</b>	944.7	222.0	23.5/-41.3/-59.5/-77.7
csched008	2/1/0	9.8	<b>1.9</b>	<b>216.9</b>	<b>52.9</b>	0.0/-10.5/-29.9/-54.6
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	17.9	<b>18.0</b>	0.0	0.0/4.3/-10.0/0.0
dano3-5	3/0/0	<b>0.1</b>	<b>35.4</b>	31.5	<b>1.1</b>	50.0/19.5/-4.4/-18.2

(continued)

Table A.12 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
dano3mip	3/0/0	<b>15.0</b>	<b>150.8</b>	72.6	17.3	12.8/46.2/-2.8/5.5
danoint	3/0/0	<b>69.6</b>	<b>2.0</b>	<b>76.2</b>	<b>22.8</b>	89.3/50.0/31.7/44.7
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>6.4</b>	<b>0.4</b>	<b>14.7</b>	0.0	-12.5/-25.0/-11.6/0.0
drayage-25-23	3/0/0	<b>3.9</b>	<b>0.6</b>	<b>19.8</b>	0.0	61.8/-33.3/-17.2/0.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0
dws008-01	0/0/3	<b>44.3</b>	<b>55.2</b>	831.3	258.0	53.8/26.0/-1.4/-8.6
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.0	1.0	0.0	0.0/9.1/0.0/0.0
enlight-hard	0/0/3	0.0	2.8	720.3	224.7	-/-/-/-
exp-1-500-5-5	3/0/0	<b>60.5</b>	0.1	28.3	<b>0.3</b>	19.8/0.0/-4.9/-100.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	961.6	<b>0.5</b>	<b>30.2</b>	<b>1.2</b>	-5.7/-20.0/-32.8/-100.0
fhnw-binpack4-48	0/0/1	0.0	44.7	1804.0	258.0	-/-/-/-
fiball	0/3/0	<b>14.4</b>	7.3	57.0	<b>5.6</b>	16.3/-4.1/-1.8/-17.9
fiber	3/0/0	153.6	0.1	15.7	0.0	0.0/0.0/-5.1/0.0
fixnet6	3/0/0	<b>58.3</b>	0.1	31.0	1.0	-26.9/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>12.5</b>	0.1	<b>4.5</b>	0.0	-16.0/0.0/-35.6/0.0
germanrr	0/3/0	<b>8.2</b>	<b>18.1</b>	<b>110.1</b>	<b>20.4</b>	-50.0/-35.4/-53.9/-71.1
gesa2	0/3/0	2.4	0.2	20.4	0.0	0.0/0.0/0.0/0.0
gesa2-o	0/3/0	<b>14.8</b>	0.2	34.6	1.6	26.0/0.0/2.8/-6.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	2/1/0	<b>980.3</b>	<b>0.4</b>	<b>146.1</b>	<b>59.8</b>	-30.5/-25.0/-28.7/-46.2
gmu-35-40	3/0/0	6.5	0.1	14.0	0.0	0.0/0.0/0.0/0.0
gmu-35-50	3/0/0	<b>9.3</b>	<b>0.5</b>	<b>54.7</b>	<b>6.8</b>	23.8/-40.0/-42.6/-85.3
graph20-20-1rand	3/0/0	<b>25.5</b>	4.4	<b>48.4</b>	<b>1.5</b>	-45.1/-6.8/-35.3/-73.3
graphdraw-domain	0/3/0	<b>65.1</b>	0.3	<b>68.5</b>	<b>16.0</b>	-55.8/0.0/-11.4/-35.0
h80x6320d	3/0/0	21.4	1.2	32.3	<b>2.3</b>	2.7/0.0/-0.9/-17.4
harp2	3/0/0	11.5	0.1	13.3	0.0	7.3/0.0/-4.5/0.0
highschool1-aigio	0/3/0	inf	<b>794.0</b>	<b>28.0</b>	<b>0.3</b>	0.0/-13.3/-45.4/-100.0
hypothyroid-k1	3/0/0	0.0	4.7	1.0	0.0	0.0/2.1/0.0/0.0
ic97p	0/0/3	14.8	4.6	757.5	222.3	3.9/9.8/14.6/-7.6
ic97t	0/0/3	12.5	3.6	978.7	275.7	-0.8/7.7/22.7/11.4
icir97p	0/0/3	20.9	<b>27.6</b>	1181.8	231.1	8.7/-21.7/-3.5/-6.7
icir97t	0/3/0	15.1	<b>7.8</b>	<b>284.4</b>	<b>163.3</b>	3.8/-43.6/-26.0/-21.1
irish-electricity	3/0/0	5.8	21.5	22.4	<b>0.0</b>	3.3/-9.8/7.4/100.0
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>11.8</b>	6.5	22.6	0.0	67.2/-1.5/-2.7/0.0
k1mushroom	3/0/0	18.2	40.2	1.0	0.0	0.0/-1.0/0.0/0.0
lectsched-5-obj	0/0/3	2437.7	83.1	833.1	9.1	-7.9/1.1/8.3/-23.1
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	674.7	1.2	90.7	57.6	0.0/-8.3/-0.8/-1.7
lotsize	2/1/0	<b>107.1</b>	<b>0.9</b>	<b>82.2</b>	<b>29.5</b>	-34.0/-44.4/-45.4/-64.4
mad	3/0/0	<b>5972.2</b>	0.1	16.3	0.0	51.7/0.0/-9.8/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>20.8</b>	48.5	<b>61.5</b>	<b>16.6</b>	53.5/2.8/-41.8/-80.7
map16715-04	3/0/0	91.1	60.9	49.9	9.2	-2.1/-6.6/-7.2/-1.1
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	494.3	0.2	90.0	<b>10.2</b>	-3.7/0.0/0.0/30.1
mas76	0/3/0	<b>128.6</b>	0.2	90.0	<b>10.5</b>	-17.7/0.0/0.8/51.2
mc11	3/0/0	97.8	0.4	43.3	13.0	9.6/0.0/-1.6/-5.4
mcsched	3/0/0	<b>16.1</b>	<b>0.6</b>	4.0	0.0	-19.9/-16.7/-10.0/0.0
mik-250-20-75-4	0/3/0	<b>51.9</b>	0.2	<b>21.0</b>	<b>2.0</b>	15.1/0.0/45.2/55.6
milo-v12-6-r2-40-1	3/0/0	<b>114.5</b>	0.9	42.3	12.3	23.8/0.0/-0.7/-2.4
misc07	3/0/0	<b>43.8</b>	0.1	21.3	0.0	-34.7/0.0/-5.6/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.12 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
mod011	3/0/0	<b>6.6</b>	0.3	19.6	0.0	52.9/0.0/0.0/0.0
modglob	3/0/0	<b>138.2</b>	0.1	31.3	1.3	-23.4/0.0/0.0/0.0
momentum1	0/0/1	211.4	72.8	1126.0	564.0	-/-/-/-
msc98-ip	3/0/0	<b>13.4</b>	5.9	28.8	<b>1.1</b>	13.5/6.3/6.2/-45.5
mushroom-best	0/3/0	9.69e06	<b>16.5</b>	44.0	<b>1.5</b>	-5.4/-17.6/-9.1/11.8
mzzv11	0/3/0	19.7	4.2	<b>24.9</b>	0.0	2.0/0.0/-22.5/0.0
mzzv42z	0/3/0	<b>27.9</b>	<b>3.9</b>	22.0	<b>0.0</b>	10.0/20.4/7.6/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>16.2</b>	<b>0.4</b>	<b>30.3</b>	<b>0.6</b>	-42.0/-25.0/-32.7/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>1.5</b>	<b>5.5</b>	<b>33.0</b>	<b>2.3</b>	-40.0/-10.9/-20.0/-73.9
neos-1171737	3/0/0	<b>5.3</b>	1.6	<b>26.5</b>	<b>1.1</b>	-26.4/0.0/10.5/-45.5
neos-1354092	0/3/0	<b>8.7</b>	166.6	41.6	<b>0.3</b>	51.9/5.5/-9.6/-100.0
neos-1445765	3/0/0	<b>31.8</b>	0.8	<b>6.4</b>	0.0	10.2/0.0/-12.5/0.0
neos-1456979	0/1/2	<b>97.2</b>	<b>46.6</b>	634.7	98.2	35.2/-13.3/-27.1/-1.7
neos-1582420	0/3/0	<b>99.8</b>	<b>4.8</b>	<b>319.0</b>	<b>53.6</b>	-30.9/-68.8/-75.1/-82.5
neos-2657525-crna	0/3/0	1004.9	<b>0.1</b>	<b>31.7</b>	<b>2.3</b>	1.1/50.0/24.2/-13.0
neos-2746589-doon	0/0/3	<b>8.7</b>	<b>884.6</b>	711.6	24.5	75.1/-84.4/-65.1/21.7
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	3/0/0	<b>0.1</b>	8.6	51.0	<b>10.7</b>	66.7/9.5/6.1/27.7
neos-3004026-krka	0/0/3	0.0	<b>88.8</b>	1122.5	3.9	0.0/18.5/12.7/-7.7
neos-3024952-loue	0/1/2	<b>1012.8</b>	<b>195.1</b>	1882.6	43.6	-19.7/-59.0/-24.9/-36.2
neos-3046615-murg	0/3/0	<b>12899.5</b>	0.2	98.1	66.5	-15.5/0.0/-3.9/-1.4
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	1/1/1	130.1	<b>80.4</b>	505.8	47.4	-7.1/82.5/53.9/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>21.6</b>	966.0	0.0	0.0/-15.3/8.3/100.0
neos-3402294-bobin	3/0/0	<b>504.4</b>	<b>26.0</b>	<b>24.8</b>	0.0	-14.9/-22.7/-23.0/0.0
neos-3555904-turama	2/0/1	<b>0.7</b>	<b>154.5</b>	107.3	3.7	65.0/-49.4/-70.7/-89.2
neos-3627168-kasai	3/0/0	<b>1.9</b>	0.1	20.4	0.0	-21.1/0.0/0.0/0.0
neos-3656078-kumeu	0/0/3	<b>24.9</b>	<b>170.8</b>	1332.3	0.0	19.2/-17.9/-21.8/100.0
neos-3754480-nidda	3/0/0	<b>2.14e05</b>	0.2	70.3	12.6	-99.8/0.0/-3.7/7.4
neos-4300652-rahue	0/0/3	<b>238.5</b>	<b>701.0</b>	712.6	0.0	10.3/-41.1/-50.2/100.0
neos-4338804-snowy	0/3/0	<b>63593.3</b>	<b>1.0</b>	<b>123.7</b>	<b>33.3</b>	44.2/-20.0/-18.8/-15.9
neos-4387871-tavua	0/0/3	<b>966.6</b>	21.4	882.0	485.5	-21.9/6.6/-9.1/-12.0
neos-4413714-turia	3/0/0	<b>9.7</b>	74.4	74.0	<b>10.9</b>	77.9/6.9/7.2/16.2
neos-4532248-waihi	1/1/1	949.4	<b>411.6</b>	361.3	74.7	0.0/15.8/17.8/-51.7
neos-4647030-tutaki	3/0/0	<b>7.7</b>	<b>26.7</b>	<b>29.2</b>	<b>0.6</b>	65.0/-34.5/-39.4/-100.0
neos-4722843-widden	0/3/0	<b>130.7</b>	<b>62.4</b>	<b>107.6</b>	26.0	33.9/-11.7/-14.1/-1.5
neos-4738912-atrato	0/3/0	<b>5.8</b>	<b>0.4</b>	<b>21.5</b>	0.0	51.7/-25.0/-42.3/0.0
neos-4763324-toguru	3/0/0	55.6	21.0	23.3	0.0	6.1/0.5/1.7/0.0
neos-4954672-berkel	3/0/0	<b>34.5</b>	0.1	<b>37.6</b>	<b>4.2</b>	36.9/0.0/-14.9/-69.0
neos-5049753-cuanza	1/0/2	<b>60.3</b>	<b>869.3</b>	368.7	79.3	20.2/-11.4/-11.7/-9.2
neos-5052403-cygnnet	3/0/0	<b>0.6</b>	41.0	2.3	0.0	53.8/2.6/0.0/0.0
neos-5093327-huahum	3/0/0	<b>780.4</b>	<b>9.5</b>	<b>100.1</b>	<b>66.4</b>	14.6/29.1/17.1/23.3
neos-5104907-jarama	1/0/1	28.8	910.4	221.4	11.7	-/-/-/-
neos-5107597-kakapo	3/0/0	39370.8	<b>2.2</b>	<b>160.6</b>	<b>125.0</b>	-0.2/-18.2/-23.2/-24.1
neos-5114902-kasavu	0/1/0	50.7	3520.3	190.0	51.0	-/-/-/-
neos-5188808-nattai	3/0/0	3986.5	<b>4.6</b>	24.9	0.0	0.7/19.3/6.7/0.0
neos-5195221-niemur	3/0/0	760.4	<b>4.3</b>	<b>9.3</b>	0.0	1.0/41.9/50.3/0.0
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	<b>286.0</b>	<b>5.2</b>	<b>16.1</b>	<b>0.8</b>	-22.0/18.8/16.6/-12.5
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>3.72e05</b>	104.2	72.3	19.9	-20.4/-0.9/-4.1/3.9
neos-860300	3/0/0	57.7	<b>0.5</b>	<b>5.3</b>	0.0	-1.2/-20.0/-24.5/0.0
neos-873061	3/0/0	<b>48.6</b>	28.1	32.0	<b>2.0</b>	20.6/-8.5/-0.9/-20.0
neos-911970	3/0/0	134.5	0.2	54.6	5.6	-1.9/0.0/-8.4/6.7
neos-933966	3/0/0	247.2	1.5	<b>11.5</b>	0.0	-9.3/6.3/-18.3/0.0
neos-950242	3/0/0	129.8	<b>9.9</b>	<b>28.6</b>	<b>1.1</b>	-1.2/-32.3/-23.8/-63.6
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.12 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-960392	1/2/0	<b>3.4</b>	<b>47.9</b>	<b>182.8</b>	<b>5.4</b>	-32.4/-57.8/-66.1/-61.1
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	1.4	8.8	1078.2	6.0	0.0/5.4/7.7/-56.7
neos17	3/0/0	295.4	0.2	32.3	1.6	-1.8/0.0/-1.9/0.0
neos20	0/1/2	<b>68.9</b>	<b>8.7</b>	1017.3	99.6	-33.7/11.2/13.9/-18.3
neos5	3/0/0	<b>68.1</b>	0.1	<b>3.3</b>	0.0	-38.9/0.0/13.2/0.0
neos7	0/3/0	<b>4.7</b>	<b>0.3</b>	<b>33.2</b>	<b>1.4</b>	57.3/-33.3/-24.7/-100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>21.9</b>	3.9	23.3	0.0	42.8/9.3/9.3/0.0
netdiversion	3/0/0	91.6	<b>66.9</b>	9.5	0.0	-5.7/10.7/1.0/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	10.3	<b>17.9</b>	1094.4	252.3	-1.0/-24.0/-0.2/2.6
nh97t	0/0/3	10.0	<b>22.9</b>	1306.1	360.4	5.7/-44.1/-16.4/-9.4
noswot	0/3/0	<b>5.0</b>	0.1	36.3	1.4	47.9/0.0/-5.5/-7.1
ns1116954	0/3/0	0.0	<b>785.7</b>	961.6	10.7	0.0/-40.0/-51.4/-70.1
ns1208400	2/1/0	0.0	<b>19.5</b>	<b>136.0</b>	<b>1.9</b>	0.0/78.4/65.6/-84.2
ns1644855	3/0/0	<b>0.6</b>	377.8	<b>39.5</b>	<b>2.6</b>	-16.7/3.3/-12.7/-34.6
ns1760995	3/0/0	<b>11.5</b>	77.5	75.0	<b>1.2</b>	22.8/8.4/6.8/58.6
ns1830653	2/0/1	<b>519.4</b>	<b>8.9</b>	231.2	9.0	-68.4/-50.6/-74.6/-88.9
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ixp	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.4	0.3	18.6	0.0	-2.9/0.0/2.1/0.0
nursesched-medium-hint03	0/3/0	837.0	<b>19.1</b>	<b>22.4</b>	0.0	-6.0/-27.2/-49.1/0.0
nursesched-sprint02	0/3/0	55.2	<b>2.7</b>	<b>15.6</b>	0.0	0.0/-29.6/-40.4/0.0
nw04	3/0/0	3.9	2.2	<b>9.0</b>	0.0	0.0/-9.1/-11.1/0.0
opm2-z10-s4	3/0/0	94.2	27.1	1.0	0.0	0.0/0.7/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	<b>0.2</b>	<b>45.5</b>	<b>5.2</b>	100.0/-50.0/-20.2/-55.8
p200x1188c	3/0/0	<b>4.4</b>	0.2	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/-
pg	3/0/0	<b>12.1</b>	0.3	56.9	19.3	21.9/0.0/-9.1/-0.5
pg5-34	3/0/0	<b>5.3</b>	0.4	54.6	13.3	25.4/0.0/-4.8/2.2
physiciansched3-3	2/0/1	<b>45.0</b>	<b>81.1</b>	131.0	7.0	-80.7/-32.8/-64.9/-85.7
physiciansched6-2	0/0/3	<b>3.1</b>	<b>72.3</b>	993.0	67.8	36.7/14.3/-25.5/-48.7
piperout-08	0/0/3	<b>202.6</b>	<b>55.8</b>	1309.7	36.6	48.7/19.4/23.4/-9.0
piperout-27	0/0/3	<b>130.5</b>	59.8	1108.2	29.1	42.9/9.4/7.4/-39.5
pk1	3/0/0	<b>685.0</b>	0.2	60.8	8.3	42.5/0.0/-4.6/6.7
pp08a	3/0/0	<b>47.1</b>	0.1	<b>20.4</b>	0.0	19.3/0.0/-23.5/0.0
pp08aCUTS	3/0/0	<b>40.4</b>	0.1	<b>19.9</b>	0.0	-13.1/0.0/-39.7/0.0
proteindesign121hz512p9	0/3/0	2.4	5.1	24.4	0.3	0.0/-2.0/0.0/0.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	3/0/0	59.7	<b>5.6</b>	<b>29.1</b>	<b>0.4</b>	9.5/33.3/23.0/-100.0
qap10	3/0/0	19.4	13.7	2.0	0.0	0.0/0.0/0.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	253.1	0.5	23.8	<b>0.3</b>	-5.1/0.0/5.9/-100.0
rB10-011001	3/0/0	202.5	<b>0.6</b>	26.2	<b>0.8</b>	0.8/-16.7/0.4/-100.0
rB11-010000	3/0/0	<b>327.3</b>	1.3	<b>26.0</b>	<b>0.4</b>	-11.8/0.0/13.3/33.3
rB11-110001	3/0/0	188.8	2.8	<b>26.0</b>	<b>0.8</b>	9.0/-7.1/-10.4/-62.5
rB12-111111	2/1/0	82.2	<b>14.2</b>	196.6	16.3	8.6/69.4/65.8/-80.4
rC10-001000	3/0/0	<b>176.8</b>	<b>0.3</b>	29.5	0.0	35.7/-33.3/-5.4/0.0
rC10-100001	3/0/0	428.7	<b>5.5</b>	<b>113.7</b>	<b>0.3</b>	-4.7/-10.9/-10.7/62.5
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>253.2</b>	<b>12.4</b>	<b>94.2</b>	<b>1.3</b>	21.3/-58.9/-61.4/-38.5
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>254.2</b>	<b>3.8</b>	<b>138.4</b>	<b>18.0</b>	-40.2/-52.6/-50.7/-80.0
radiationm40-10-02	0/3/0	<b>2670.9</b>	<b>26.3</b>	<b>259.9</b>	<b>28.3</b>	-83.9/-38.4/-44.7/-68.2
rail01	3/0/0	34.2	1199.4	<b>15.7</b>	0.0	-9.4/6.3/-24.2/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.1	1.0	0.0	0.0/8.3/0.0/0.0
ran14x18-disj-8	3/0/0	<b>22.2</b>	0.3	21.2	<b>0.0</b>	-25.2/0.0/7.0/100.0

(continued)

Table A.12 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
rd-rplusc-21	0/0/3	57.2	36.2	918.3	395.6	1.5/0.0/-5.6/-8.8
reblock115	2/1/0	<b>9.9</b>	<b>2.2</b>	<b>81.0</b>	<b>11.0</b>	11.6/-27.3/-31.6/-43.6
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.2	2.0	0.0	0.0/-0.7/0.0/0.0
rocl-4-11	0/0/3	<b>60.3</b>	<b>18.2</b>	878.0	120.2	12.9/14.2/5.8/-13.6
rocll-5-11	1/1/1	<b>75.2</b>	<b>13.5</b>	256.1	85.6	16.8/-37.8/-39.0/-38.6
roi2alpha3n4	3/0/0	<b>33.4</b>	33.6	35.1	<b>1.3</b>	46.5/-0.9/-2.3/18.8
roi5alpha10n8	3/0/0	58.2	<b>573.9</b>	<b>37.9</b>	<b>2.9</b>	3.2/-22.2/-23.5/-100.0
roll3000	0/3/0	<b>35.3</b>	<b>1.5</b>	<b>79.8</b>	<b>15.8</b>	-25.8/-26.7/-39.3/-71.5
rout	0/3/0	<b>43.9</b>	<b>0.2</b>	<b>42.6</b>	<b>4.6</b>	11.3/0.0/-17.4/-63.0
s100	3/0/0	<b>2.8</b>	<b>243.2</b>	<b>4.0</b>	0.0	-39.3/19.7/39.4/0.0
s250r10	3/0/0	0.1	53.1	2.0	0.0	0.0/0.6/0.0/0.0
satellites2-40	0/3/0	<b>321.1</b>	<b>65.9</b>	<b>147.0</b>	<b>57.0</b>	-23.6/-32.9/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>93.6</b>	409.8	182.5	-60.0/-75.9/-91.5/-98.5
savshed1	0/3/0	8.6	199.2	13.0	0.0	-8.1/-4.6/-5.4/0.0
sct2	3/0/0	28.6	0.6	24.4	<b>0.0</b>	2.1/0.0/6.5/100.0
set1ch	3/0/0	<b>67.8</b>	0.1	31.0	1.0	20.8/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	1.5	<b>3.3</b>	<b>9.4</b>	0.0	-6.7/-18.2/-19.1/0.0
sing326	3/0/0	<b>14.6</b>	<b>29.8</b>	<b>42.1</b>	<b>4.2</b>	-27.4/-17.1/-19.2/-61.9
sing44	3/0/0	7.7	27.9	41.0	<b>4.3</b>	-3.9/-5.4/-6.1/-11.6
snp-02-004-104	0/3/0	<b>2.2</b>	20.4	34.0	1.9	-22.7/-3.4/-1.2/0.0
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.7	<b>1.6</b>	0.0/0.0/-1.3/-18.8
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	98.8	62.4	13.2	0.0	-0.2/-0.5/-1.5/0.0
square41	0/3/0	6.7	1212.6	11.0	0.0	0.0/0.7/-9.1/0.0
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>147.5</b>	111.8	12.3	0.0	13.4/-1.5/9.6/0.0
supportcase12	0/3/0	<b>2.2</b>	14.6	<b>23.5</b>	0.0	-18.2/0.0/-10.6/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>3142.4</b>	0.2	90.0	59.7	66.5/0.0/-0.3/5.7
supportcase33	0/3/0	61.6	<b>27.9</b>	<b>328.3</b>	<b>60.9</b>	4.5/-50.5/-63.1/-76.2
supportcase40	3/0/0	<b>21.7</b>	4.4	18.0	0.0	-18.9/-4.5/-7.8/0.0
supportcase42	0/3/0	<b>17.1</b>	<b>6.4</b>	<b>17.2</b>	0.0	29.9/-34.4/-32.6/0.0
supportcase6	3/0/0	<b>7.6</b>	<b>17.7</b>	<b>18.8</b>	0.0	-94.7/-24.9/-36.2/0.0
supportcase7	3/0/0	<b>10.5</b>	8.8	26.0	0.0	26.6/-5.7/0.0/0.0
swath	0/2/1	<b>210.0</b>	<b>50.4</b>	599.7	223.6	-13.5/-73.2/-68.7/-73.3
swath1	3/0/0	<b>16.6</b>	<b>0.9</b>	<b>38.0</b>	<b>3.6</b>	72.5/60.9/38.9/77.1
swath3	3/0/0	<b>12.0</b>	<b>1.0</b>	<b>37.3</b>	<b>3.6</b>	63.9/33.3/13.1/-11.1
t1717	3/0/0	<b>153.6</b>	137.4	<b>60.3</b>	0.0	14.3/-8.1/-27.9/0.0
tbfp-network	3/0/0	<b>36.7</b>	<b>15.4</b>	<b>15.6</b>	0.0	81.6/31.2/-10.3/0.0
thor50dday	3/0/0	257.8	7.3	24.5	1.7	0.0/-1.4/0.0/0.0
timtab1	0/3/0	<b>68.6</b>	<b>0.8</b>	<b>134.8</b>	<b>57.0</b>	-19.1/-25.0/-15.7/-51.1
timtab2	0/0/3	66.9	<b>11.2</b>	1084.6	397.2	9.1/-48.2/-27.0/-31.9
tr12-30	3/0/0	<b>50.3</b>	0.2	33.3	<b>2.4</b>	31.0/0.0/-4.8/-33.3
traininstance2	0/1/2	<b>176.6</b>	<b>3.8</b>	640.4	71.8	27.5/-13.2/1.4/-4.5
traininstance6	0/3/0	<b>65.3</b>	<b>0.9</b>	226.1	33.6	85.9/25.0/26.1/20.2
trento1	3/0/0	<b>219.2</b>	8.7	<b>11.2</b>	0.0	-14.6/-8.0/-17.0/0.0
triptim1	0/3/0	0.1	22.5	4.2	0.0	0.0/3.4/-4.8/0.0
uccase12	3/0/0	1.9	10.7	16.6	0.0	0.0/-3.7/-6.0/0.0
uccase9	3/0/0	<b>4561.8</b>	<b>32.5</b>	100.3	42.4	18.7/43.9/47.1/41.9
uct-subprob	3/0/0	<b>14.9</b>	<b>0.5</b>	<b>9.6</b>	0.0	-16.8/16.7/-19.8/0.0
unitcal-7	0/0/3	<b>20.7</b>	<b>119.4</b>	867.6	69.8	22.8/13.3/12.5/52.2
var-smallemercy-m6j6	3/0/0	<b>138.9</b>	24.0	68.9	10.1	45.8/0.0/-2.0/0.0
vpmp2	3/0/0	44.3	0.1	<b>28.6</b>	<b>0.3</b>	1.6/0.0/-28.7/-100.0
wachplan	0/3/0	0.0	<b>2.3</b>	27.5	<b>0.3</b>	0.0/23.3/-3.6/-100.0
Geom. means		(270 instances)	(226 instances)			
FP		45.5	5.3	15.5	1.1	

(continued)

Table A.12 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
FP+(3,l,h)		<b>43.1</b>	<b>5.6</b>	<b>17.1</b>	<b>1.4</b>	

Table A.13.: Performance of FP+(5,l,h)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	0/3/0	<b>4.9</b>	13.0	<b>282.1</b>	<b>31.1</b>	59.5/-6.2/-43.4/-96.1
30n20b8	0/0/3	<b>560.7</b>	<b>22.7</b>	819.5	316.1	-17.6/-74.9/-79.6/-90.9
50v-10	0/3/0	<b>156.3</b>	0.3	23.3	<b>0.6</b>	-20.2/0.0/-1.3/-50.0
CMS750-4	3/0/0	48.0	<b>13.4</b>	<b>228.4</b>	<b>31.2</b>	9.4/-69.4/-71.5/-61.5
a1c1s1	3/0/0	<b>26.2</b>	<b>0.7</b>	34.6	<b>2.9</b>	50.4/-42.9/-9.5/-55.2
academicimetablesmall	0/0/3	inf	552.1	1331.5	5.5	-/-/-/-
aflow30a	3/0/0	<b>191.4</b>	<b>0.3</b>	<b>60.8</b>	<b>12.7</b>	-31.2/-66.7/-44.9/-84.3
aflow40b	3/0/0	223.3	0.3	<b>35.6</b>	<b>3.5</b>	-7.2/0.0/-10.1/-57.1
air04	3/0/0	<b>0.4</b>	<b>3.6</b>	<b>15.4</b>	<b>0.3</b>	-75.0/-27.8/-57.1/-100.0
air05	3/0/0	<b>3.1</b>	<b>1.6</b>	<b>16.7</b>	0.0	24.4/-50.0/-76.0/0.0
app1-1	3/0/0	<b>15.6</b>	<b>1.0</b>	<b>63.4</b>	<b>15.7</b>	-80.1/-50.0/-45.4/-74.5
app1-2	1/2/0	43.9	<b>24.8</b>	<b>144.5</b>	<b>56.4</b>	0.0/-56.9/-64.2/-72.9
arki001	0/0/3	<b>2.0</b>	<b>24.9</b>	1081.3	355.9	31.0/-16.9/-25.6/-47.6
assign1-5-8	3/0/0	<b>3.0</b>	0.1	<b>25.9</b>	0.0	-36.7/0.0/-13.9/0.0
atlanta-ip	3/0/0	<b>10.7</b>	17.2	25.8	<b>0.3</b>	40.6/-1.7/0.0/50.0
b1c1s1	3/0/0	170.1	<b>1.0</b>	<b>43.3</b>	<b>7.3</b>	-5.2/-50.0/-22.2/-50.7
bab2	0/1/2	<b>8.9</b>	<b>693.9</b>	610.1	103.0	65.1/-54.7/-71.6/-77.2
bab6	0/0/3	<b>11.9</b>	<b>588.8</b>	872.2	217.8	49.8/-82.3/-89.9/-93.0
beasleyC3	3/0/0	<b>13.1</b>	<b>0.3</b>	<b>56.8</b>	<b>13.5</b>	-11.5/-33.3/-38.4/-64.4
binkar10-1	3/0/0	3.9	0.1	<b>11.4</b>	<b>0.4</b>	2.5/0.0/27.4/-100.0
blp-ar98	3/0/0	68.5	2.2	18.3	0.0	3.9/-9.1/-7.7/0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/0	-	-	-	-	-/-/-/-
bppc4-08	3/0/0	<b>26.0</b>	<b>1.0</b>	62.3	8.9	49.6/16.7/0.0/4.3
brazil3	0/3/0	<b>268.7</b>	20.2	<b>28.8</b>	0.0	57.7/4.3/-25.7/0.0
buildingenergy	0/3/0	1.1	635.5	11.0	0.0	0.0/8.8/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	inf	<b>7.2</b>	<b>80.7</b>	<b>25.9</b>	-100.0/-62.5/-50.4/-61.4
chromaticindex1024-7	3/0/0	0.0	54.8	<b>2.3</b>	0.0	0.0/0.0/23.3/0.0
chromaticindex512-7	3/0/0	0.0	44.9	2.0	0.0	0.0/0.2/0.0/0.0
cmflsp50-24-8-8	1/2/0	<b>14.7</b>	<b>56.2</b>	439.1	157.3	24.6/66.4/58.2/46.6
co-100	3/0/0	302.1	6.3	15.7	0.0	0.2/-3.2/-0.6/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	3731.7	6.8	<b>28.6</b>	0.0	-8.2/-8.8/-16.1/0.0
comp21-2idx	0/3/0	409.1	5.1	<b>30.3</b>	<b>0.4</b>	4.2/-9.8/-17.2/-100.0
cost266-UUE	3/0/0	<b>31.2</b>	<b>0.5</b>	<b>32.6</b>	<b>1.6</b>	11.1/-20.0/-27.9/-81.2
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/1/2	<b>33.1</b>	6.3	656.8	180.8	52.0/-3.2/-41.8/-72.7
csched008	1/1/1	9.4	<b>2.9</b>	311.7	82.0	4.1/-41.4/-51.2/-70.7
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	19.1	<b>18.0</b>	0.0	0.0/-2.1/-10.0/0.0
dano3-5	3/0/0	<b>0.1</b>	<b>36.6</b>	<b>34.6</b>	<b>2.2</b>	50.0/16.8/-13.0/-59.1
dano3mip	3/0/0	<b>12.3</b>	<b>123.8</b>	72.3	<b>16.3</b>	28.5/55.8/-2.4/10.9
danooint	1/2/0	<b>209.8</b>	3.8	<b>177.1</b>	<b>63.3</b>	67.8/5.0/-37.0/-34.9
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>7.5</b>	<b>0.4</b>	<b>15.2</b>	0.0	-25.3/-25.0/-14.5/0.0
drayage-25-23	3/0/0	10.9	<b>0.6</b>	<b>21.1</b>	0.0	-6.4/-33.3/-22.3/0.0
ds	3/0/0	4945.0	6.0	1.0	0.0	0.0/0.0/0.0/0.0
dws008-01	0/0/3	<b>32.6</b>	<b>51.9</b>	920.1	376.3	66.0/30.4/-10.9/-37.4
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0	0.0/0.0/0.0/0.0
enlight-hard	0/0/2	0.0	4.3	763.6	248.4	-/-/-/-
exp-1-500-5-5	3/0/0	<b>52.8</b>	0.1	<b>30.6</b>	<b>0.4</b>	30.0/0.0/-12.1/-100.0

(continued)

Table A.13 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>677.1</b>	0.4	<b>25.6</b>	<b>0.8</b>	25.4/0.0/-20.7/-100.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>12.3</b>	<b>8.3</b>	61.2	<b>7.8</b>	28.5/-15.7/-8.5/-41.0
fiber	3/0/0	160.5	0.1	16.3	0.0	-4.3/0.0/-8.6/0.0
fixnet6	3/0/0	<b>57.2</b>	0.1	31.0	1.0	-25.5/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>12.5</b>	0.1	<b>4.5</b>	0.0	-16.0/0.0/-35.6/0.0
germanrr	0/3/0	<b>10.6</b>	<b>21.0</b>	<b>146.6</b>	<b>37.9</b>	-61.3/-44.3/-65.3/-84.4
gesa2	0/3/0	2.6	<b>0.3</b>	<b>31.6</b>	<b>1.1</b>	-7.7/-33.3/-35.4/-100.0
gesa2-o	0/3/0	19.7	<b>0.3</b>	<b>47.0</b>	<b>3.8</b>	1.5/-33.3/-24.3/-60.5
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	1/2/0	<b>553.0</b>	<b>0.8</b>	<b>268.0</b>	<b>109.8</b>	18.9/-62.5/-61.1/-70.7
gmu-35-40	3/0/0	6.9	0.1	14.0	0.0	-5.8/0.0/0.0/0.0
gmu-35-50	3/0/0	11.1	<b>0.6</b>	<b>62.1</b>	<b>10.0</b>	9.0/-50.0/-49.4/-90.0
graph20-20-1rand	3/0/0	<b>33.3</b>	<b>5.2</b>	<b>65.5</b>	<b>2.6</b>	-58.0/-21.2/-52.2/-84.6
graphdraw-domain	0/3/0	<b>196.1</b>	<b>0.8</b>	<b>152.0</b>	<b>41.1</b>	-85.3/-62.5/-60.1/-74.7
h80x6320d	3/0/0	23.5	1.3	<b>35.6</b>	<b>3.6</b>	-6.4/-7.7/-10.1/-47.2
harp2	3/0/0	12.1	0.1	12.7	0.0	2.4/0.0/0.0/0.0
highschool1-aigio	0/3/0	inf	<b>775.8</b>	<b>24.3</b>	0.0	0.0/-11.2/-37.0/0.0
hypothyroid-k1	3/0/0	0.0	4.7	1.0	0.0	0.0/2.1/0.0/0.0
ic97p	0/3/0	<b>11.4</b>	4.7	724.7	310.6	26.0/7.8/18.3/-33.9
ic97t	0/0/3	13.0	4.1	1216.9	399.7	-4.6/-4.9/3.9/-22.1
icir97p	0/0/3	<b>19.6</b>	<b>39.4</b>	1422.5	326.9	14.4/-45.2/-19.9/-34.0
icir97t	0/2/1	<b>10.7</b>	<b>14.0</b>	428.1	193.3	31.8/-68.6/-50.8/-33.4
irish-electricity	2/1/0	<b>7.7</b>	<b>31.3</b>	<b>47.8</b>	<b>3.7</b>	-22.1/-38.0/-49.4/-91.9
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>31.1</b>	6.4	23.3	0.0	13.6/0.0/-5.6/0.0
k1mushroom	3/0/0	18.2	40.0	1.0	0.0	0.0/-0.5/0.0/0.0
lectsched-5-obj	0/0/3	<b>1811.5</b>	<b>147.2</b>	1497.5	1.1	19.3/-42.9/-39.3/84.3
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>340.9</b>	1.2	90.3	<b>37.5</b>	49.5/-8.3/-0.3/33.7
lotsize	1/1/1	<b>304.2</b>	<b>3.2</b>	307.6	136.9	-76.8/-84.4/-85.4/-92.3
mad	3/0/0	<b>6502.0</b>	<b>0.2</b>	<b>18.6</b>	0.0	47.4/-50.0/-21.0/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>36.6</b>	54.2	<b>68.5</b>	<b>18.5</b>	18.1/-7.9/-47.7/-82.7
map16715-04	3/0/0	<b>62.8</b>	<b>63.4</b>	<b>57.6</b>	<b>13.6</b>	29.6/-10.3/-19.6/-33.1
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>1233.3</b>	0.2	90.0	<b>10.5</b>	-61.4/0.0/0.0/28.1
mas76	0/3/0	<b>155.6</b>	0.2	90.0	<b>9.9</b>	-32.0/0.0/0.8/54.0
mc11	3/0/0	<b>141.7</b>	<b>1.1</b>	<b>114.7</b>	<b>43.9</b>	-23.6/-63.6/-62.9/-72.0
mcsched	3/0/0	<b>20.2</b>	<b>0.6</b>	<b>4.3</b>	0.0	-36.1/-16.7/-16.3/0.0
mik-250-20-75-4	0/3/0	<b>53.9</b>	0.2	<b>22.7</b>	<b>2.7</b>	11.8/0.0/40.7/40.0
milo-v12-6-r2-40-1	3/0/0	<b>110.6</b>	<b>2.4</b>	<b>119.8</b>	<b>46.1</b>	26.4/-62.5/-64.9/-74.0
misc07	3/0/0	<b>20.3</b>	0.1	<b>23.0</b>	0.0	29.0/0.0/-12.6/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>41.1</b>	<b>0.4</b>	20.7	0.0	-65.9/-25.0/-5.3/0.0
modglob	3/0/0	113.9	0.1	31.7	1.3	-7.0/0.0/-1.3/0.0
momentum1	0/0/2	115.2	58.2	958.7	457.1	-/-/-/-
msc98-ip	3/0/0	14.9	6.8	<b>37.4</b>	<b>1.9</b>	3.9/-7.4/-17.9/-68.4
mushroom-best	0/3/0	<b>2.09e06</b>	<b>24.7</b>	<b>65.7</b>	<b>4.5</b>	77.2/-44.9/-39.1/-62.2
mzzv11	0/3/0	20.6	4.4	<b>30.4</b>	<b>0.6</b>	-2.4/-4.5/-36.5/-100.0
mzzv42z	0/3/0	<b>22.2</b>	<b>3.9</b>	23.3	<b>0.0</b>	28.4/20.4/2.1/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>11.0</b>	<b>0.5</b>	<b>31.6</b>	<b>1.1</b>	-14.5/-40.0/-35.4/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0

(continued)



Table A.13 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-1171448	3/0/0	<i>10.5</i>	<i>5.5</i>	<i>33.0</i>	<i>2.0</i>	-91.4/-10.9/-20.0/-70.0
neos-1171737	3/0/0	<i>9.1</i>	<i>1.4</i>	<i>22.9</i>	<i>0.4</i>	-57.1/12.5/22.6/33.3
neos-1354092	0/3/0	<b>6.6</b>	175.0	<i>54.2</i>	0.0	63.5/0.7/-30.6/0.0
neos-1445765	3/0/0	32.1	<b>0.7</b>	5.5	0.0	9.3/12.5/1.8/0.0
neos-1456979	0/0/3	<b>94.9</b>	<i>114.8</i>	1320.8	107.6	36.7/-64.8/-65.0/-10.3
neos-1582420	0/3/0	<b>40.9</b>	<i>3.1</i>	<i>188.4</i>	<i>28.4</i>	40.7/-51.6/-57.8/-66.9
neos-2657525-crna	0/3/0	960.9	<i>0.4</i>	<i>63.7</i>	<i>10.1</i>	5.5/-50.0/-34.4/-80.2
neos-2746589-doon	0/0/3	<b>7.0</b>	<i>274.7</i>	749.3	73.1	79.9/-49.7/-66.9/-57.2
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	3/0/0	<b>0.1</b>	8.8	52.8	<b>11.1</b>	66.7/7.4/2.8/25.0
neos-3004026-krka	0/0/3	0.0	104.0	939.0	4.0	0.0/4.6/27.0/-10.0
neos-3024952-loue	0/0/3	<b>651.7</b>	<i>298.5</i>	1622.6	0.0	19.8/-73.2/-12.8/100.0
neos-3046615-murg	0/3/0	10554.6	0.2	<i>105.6</i>	<b>48.6</b>	3.2/0.0/-10.7/25.9
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	<i>134.8</i>	<b>150.9</b>	882.8	109.9	-10.3/67.1/19.5/-100.0
neos-3381206-awhea	0/0/3	4.9	<i>37.6</i>	1304.3	0.6	0.0/-51.3/-19.2/45.5
neos-3402294-bobin	3/0/0	<i>491.1</i>	<i>32.8</i>	<i>32.6</i>	<i>1.7</i>	-12.6/-38.7/-41.4/-100.0
neos-3555904-turama	2/0/1	<i>4.3</i>	<i>176.3</i>	112.4	2.5	-53.5/-55.6/-72.1/-84.0
neos-3627168-kasai	3/0/0	<i>1.9</i>	0.1	20.4	0.0	-21.1/0.0/0.0/0.0
neos-3656078-kumeu	0/0/3	34.2	<b>121.9</b>	776.6	0.0	-9.9/13.1/25.4/100.0
neos-3754480-nidda	3/0/0	378.9	0.2	69.0	<b>11.2</b>	-3.5/0.0/-1.9/17.6
neos-4300652-rahue	0/1/2	<b>207.3</b>	375.9	454.5	2.7	22.0/9.0/-22.0/-88.9
neos-4338804-snowy	0/3/0	<b>33457.8</b>	<i>1.5</i>	<i>167.8</i>	<i>46.5</i>	70.7/-46.7/-40.1/-39.8
neos-4387871-tavua	0/0/3	<b>149.0</b>	<b>18.7</b>	760.7	352.0	80.3/18.3/5.2/17.6
neos-4413714-turia	3/0/0	<i>2.9</i>	72.0	<b>70.8</b>	<b>10.6</b>	93.4/9.9/11.2/18.5
neos-4532248-waihi	0/1/2	949.4	<i>598.1</i>	798.2	281.4	0.0/-18.2/-44.9/-87.2
neos-4647030-tutaki	3/0/0	<b>12.0</b>	<i>22.4</i>	<i>23.5</i>	<i>0.3</i>	45.5/-21.9/-24.7/-100.0
neos-4722843-widden	0/3/0	<b>20.0</b>	<i>89.4</i>	<i>152.5</i>	<i>39.9</i>	89.9/-38.4/-39.4/-35.8
neos-4738912-atrato	0/3/0	<i>6.5</i>	<i>0.4</i>	<i>21.5</i>	0.0	45.8/-25.0/-42.3/0.0
neos-4763324-toguru	3/0/0	60.3	21.4	24.0	0.0	-1.8/-1.4/-1.3/0.0
neos-4954672-berkel	3/0/0	51.8	0.1	<i>35.8</i>	<i>3.1</i>	5.3/0.0/-10.6/-58.1
neos-5049753-cuanza	1/0/2	<b>40.3</b>	756.8	359.2	109.7	46.7/1.8/-9.4/-34.4
neos-5052403-cygnnet	3/0/0	<b>0.6</b>	41.4	2.3	0.0	53.8/1.7/0.0/0.0
neos-5093327-huahum	3/0/0	<b>65.8</b>	<b>7.4</b>	<b>86.9</b>	<b>36.7</b>	92.8/44.8/28.0/57.6
neos-5104907-jarama	0/0/3	46.6	1833.5	779.2	21.5	-/-/-/-
neos-5107597-kakapo	0/3/0	<b>23872.1</b>	<i>7.1</i>	<i>623.2</i>	<i>324.2</i>	39.3/-74.6/-80.2/-70.7
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	<i>4656.3</i>	<b>4.7</b>	26.3	0.0	-13.8/17.5/1.5/0.0
neos-5195221-niemur	3/0/0	<b>661.2</b>	<b>5.8</b>	<b>14.7</b>	0.0	13.9/21.6/21.4/0.0
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	<i>343.3</i>	<b>5.4</b>	<b>16.6</b>	0.7	-35.0/15.6/14.0/0.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<i>6.16e05</i>	106.7	73.6	20.3	-51.9/-3.2/-5.8/1.9
neos-860300	3/0/0	59.0	<i>0.5</i>	<i>6.0</i>	0.0	-3.4/-20.0/-33.3/0.0
neos-873061	3/0/0	58.4	<i>29.9</i>	33.3	<i>2.2</i>	4.6/-14.0/-4.8/-27.3
neos-911970	3/0/0	<i>201.1</i>	0.2	54.6	<b>3.7</b>	-34.4/0.0/-8.4/38.3
neos-933966	3/0/0	<b>196.8</b>	1.5	<i>11.2</i>	0.0	12.2/6.3/-16.1/0.0
neos-950242	3/0/0	<b>63.0</b>	<b>5.9</b>	21.5	<b>0.0</b>	50.9/11.9/1.4/100.0
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	1/1/1	<b>1.6</b>	<i>74.9</i>	298.0	22.4	30.4/-73.0/-79.2/-90.6
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<b>0.9</b>	10.1	1046.7	20.4	35.7/-7.9/10.4/-87.3
neos17	3/0/0	284.4	0.2	33.3	<i>2.2</i>	2.0/0.0/-4.8/-27.3
neos20	0/0/3	<i>55.7</i>	<i>16.8</i>	1809.9	134.0	-18.0/-41.7/-34.7/-39.3
neos5	3/0/0	<i>68.1</i>	0.1	<b>3.3</b>	0.0	-38.9/0.0/13.2/0.0
neos7	0/3/0	11.0	<i>0.5</i>	<i>45.3</i>	<i>3.2</i>	0.0/-60.0/-44.8/-100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>6.4</b>	<b>3.4</b>	<b>18.9</b>	0.0	83.3/20.9/26.5/0.0
netdiversion	3/0/0	86.6	67.9	9.6	0.0	-0.2/9.3/0.0/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.13 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
nh97p	0/0/3	10.0	<i>18.6</i>	1011.0	322.9	2.0/-26.9/7.5/-19.8
nh97t	0/1/2	11.3	<i>31.0</i>	1570.9	429.0	-6.2/-58.7/-30.5/-23.9
noswot	0/3/0	<b>8.3</b>	0.1	<i>42.8</i>	<i>3.8</i>	13.5/0.0/-19.9/-65.8
ns1116954	0/0/3	0.0	<i>1140.0</i>	1463.4	17.6	0.0/-58.6/-68.1/-81.8
ns1208400	1/2/0	0.0	<b>26.5</b>	<b>196.4</b>	<i>4.9</i>	0.0/70.6/50.3/-93.9
ns1644855	3/0/0	<i>13.2</i>	<i>708.3</i>	<i>63.9</i>	<i>15.0</i>	-96.2/-44.9/-46.0/-88.7
ns1760995	3/0/0	<b>11.0</b>	<b>73.0</b>	75.7	2.7	26.2/13.7/6.0/6.9
ns1830653	1/2/0	<i>283.4</i>	<i>4.9</i>	<i>114.3</i>	<i>2.0</i>	-42.1/-10.2/-48.6/-50.0
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-1px	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.6	0.3	18.6	0.0	-8.3/0.0/2.1/0.0
nursesched-medium-hint03	0/3/0	807.4	<i>18.8</i>	<i>21.3</i>	0.0	-2.6/-26.1/-46.5/0.0
nursesched-sprint02	0/3/0	55.2	<i>2.6</i>	<i>15.0</i>	0.0	0.0/-26.9/-38.0/0.0
nw04	3/0/0	3.7	<i>2.3</i>	<i>9.5</i>	0.0	5.1/-13.0/-15.8/0.0
opm2-z10-s4	3/0/0	94.2	27.3	1.0	0.0	0.0/0.0/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	<i>0.2</i>	<i>44.6</i>	<i>3.4</i>	100.0/-50.0/-18.6/-32.4
p200x1188c	3/0/0	<i>4.4</i>	0.2	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/2	0.0	468.3	886.0	11.0	-/-/-/-
pg	3/0/0	<b>3.5</b>	0.3	55.3	<b>12.5</b>	77.4/0.0/-6.5/34.9
pg5-34	3/0/0	<b>3.1</b>	0.4	54.0	<b>11.0</b>	56.3/0.0/-3.7/19.1
physiciansched3-3	2/0/1	<i>122.3</i>	<i>83.1</i>	160.5	20.7	-92.9/-34.4/-71.3/-95.2
physiciansched6-2	0/0/3	<b>3.5</b>	<b>67.2</b>	877.7	69.7	28.6/20.4/-15.7/-50.1
piperout-08	0/0/3	<b>192.7</b>	65.8	1494.2	23.0	51.2/4.9/12.7/30.9
piperout-27	0/0/3	<b>130.4</b>	60.6	1084.7	25.4	42.9/8.2/9.4/-30.7
pk1	3/0/0	<b>473.3</b>	0.2	61.6	<b>7.4</b>	60.3/0.0/-5.8/16.9
pp08a	3/0/0	<i>81.8</i>	0.1	<i>20.4</i>	0.0	-28.6/0.0/-23.5/0.0
pp08aCUTS	3/0/0	<b>18.2</b>	0.1	<i>24.8</i>	0.0	48.1/0.0/-51.6/0.0
proteindesign121hz512p9	0/3/0	2.4	4.8	22.5	<b>0.0</b>	0.0/4.0/7.8/100.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	3/0/0	<b>47.1</b>	<b>5.6</b>	<b>32.9</b>	0.0	28.6/33.3/13.0/0.0
qap10	3/0/0	19.4	13.8	2.0	0.0	0.0/-0.7/0.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	253.4	0.5	26.2	<i>0.3</i>	-5.2/0.0/-3.4/-100.0
rB10-011001	3/0/0	199.3	<i>0.6</i>	26.2	<i>0.3</i>	2.4/-16.7/0.4/-100.0
rB11-010000	3/0/0	278.9	1.3	28.8	<b>0.3</b>	3.4/0.0/4.0/50.0
rB11-110001	3/0/0	<b>127.8</b>	<i>3.8</i>	<i>43.6</i>	<i>0.4</i>	38.4/-31.6/-46.6/-25.0
rB12-111111	0/3/0	<b>66.8</b>	<b>33.3</b>	515.5	77.3	25.7/28.2/10.3/-95.9
rC10-001000	3/0/0	<b>122.9</b>	<i>0.5</i>	<i>51.4</i>	<i>1.7</i>	55.3/-60.0/-45.7/-100.0
rC10-100001	1/2/0	<i>576.0</i>	<i>7.8</i>	<i>162.1</i>	<b>0.6</b>	-29.1/-37.2/-37.4/25.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<i>517.9</i>	<i>10.3</i>	<i>68.1</i>	<b>0.0</b>	-37.9/-50.5/-46.5/100.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<i>259.4</i>	<i>10.6</i>	<i>341.4</i>	<i>75.5</i>	-41.4/-83.0/-80.0/-95.2
radiationm40-10-02	0/3/0	<i>3509.1</i>	<i>92.2</i>	<i>692.1</i>	<i>31.0</i>	-87.7/-82.4/-79.2/-71.0
rail01	3/0/0	30.1	<b>1041.0</b>	<i>17.3</i>	0.0	2.9/18.7/-31.2/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<i>24.2</i>	0.3	21.2	<b>0.0</b>	-31.4/0.0/7.0/100.0
rd-rplusc-21	0/0/3	55.4	38.5	924.4	400.3	4.6/-6.0/-6.3/-9.9
reblock115	3/0/0	<b>8.7</b>	<i>2.0</i>	<i>73.3</i>	<i>12.8</i>	22.3/-20.0/-24.4/-51.6
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.1	2.0	0.0	0.0/0.0/0.0/0.0
rocl-4-11	0/0/3	66.4	<i>25.1</i>	1195.0	263.0	4.0/-15.5/-22.0/-60.5
rocll-5-11	0/0/3	<b>67.9</b>	<i>57.3</i>	1177.2	491.4	24.9/-85.3/-86.7/-89.3
roi2alpha3n4	3/0/0	<b>39.4</b>	<i>39.8</i>	<i>39.3</i>	<i>3.3</i>	36.9/-16.3/-12.7/-51.5
roi5alpha10n8	3/0/0	57.0	<i>542.6</i>	<i>36.3</i>	<i>2.3</i>	5.2/-17.7/-20.1/-100.0
roll3000	0/3/0	<i>33.1</i>	<i>1.3</i>	<i>69.0</i>	<i>11.0</i>	-20.8/-15.4/-29.9/-59.1
rout	0/3/0	<b>43.5</b>	<i>0.3</i>	<i>73.8</i>	<i>17.2</i>	12.1/-33.3/-52.3/-90.1
s100	3/0/0	<i>2.8</i>	<b>241.5</b>	<b>4.0</b>	0.0	-39.3/20.2/39.4/0.0

(continued)

Table A.13 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
s250r10	3/0/0	0.1	53.2	2.0	0.0	0.0/0.4/0.0/0.0
satellites2-40	0/3/0	<b>321.1</b>	<b>62.8</b>	<b>147.0</b>	<b>57.0</b>	-23.6/-29.6/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>84.9</b>	415.4	185.3	-60.0/-73.4/-91.6/-98.5
savsched1	0/3/0	8.4	199.3	13.0	0.0	-6.0/-4.6/-5.4/0.0
sct2	3/0/0	<b>26.0</b>	<b>0.7</b>	28.8	<b>0.3</b>	11.0/-14.3/-9.4/50.0
set1ch	3/0/0	<b>50.8</b>	0.1	31.0	1.0	40.7/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<b>8.6</b>	3.0	<b>8.6</b>	0.0	-83.7/-10.0/-11.6/0.0
sing326	3/0/0	<b>12.0</b>	<b>31.6</b>	<b>45.3</b>	<b>6.0</b>	-11.7/-21.8/-24.9/-73.3
sing44	3/0/0	<b>9.2</b>	<b>30.9</b>	<b>46.8</b>	<b>6.3</b>	-19.6/-14.6/-17.7/-39.7
snp-02-004-104	0/3/0	<b>2.8</b>	<b>24.2</b>	<b>40.3</b>	<b>5.5</b>	-39.3/-18.6/-16.6/-65.5
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	33.3	<b>2.2</b>	0.0/0.0/-6.0/-40.9
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.2	<b>54.7</b>	<b>8.0</b>	0.0	-0.6/11.9/38.5/0.0
square41	0/3/0	6.7	1281.0	11.0	0.0	0.0/-4.7/-9.1/0.0
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>110.5</b>	112.1	12.3	0.0	35.1/-1.8/9.6/0.0
supportcase12	0/3/0	<b>2.1</b>	15.8	<b>24.8</b>	0.0	-14.3/-7.6/-15.3/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>4288.7</b>	<b>0.3</b>	<b>112.6</b>	<b>42.2</b>	54.3/-33.3/-20.3/33.3
supportcase33	0/3/0	<b>72.4</b>	<b>23.4</b>	<b>304.2</b>	<b>48.2</b>	-10.9/-41.0/-60.1/-69.9
supportcase40	3/0/0	<b>21.1</b>	<b>4.8</b>	<b>21.3</b>	0.0	-16.6/-12.5/-22.1/0.0
supportcase42	0/3/0	<b>17.1</b>	<b>6.3</b>	<b>16.1</b>	0.0	29.9/-33.3/-28.0/0.0
supportcase6	3/0/0	<b>0.6</b>	<b>15.4</b>	<b>16.0</b>	0.0	-33.3/-13.6/-25.0/0.0
supportcase7	3/0/0	<b>18.0</b>	<b>9.3</b>	27.6	<b>0.3</b>	-20.6/-10.8/-5.8/-100.0
swath	0/0/3	<b>163.4</b>	<b>53.3</b>	684.7	261.6	10.0/-74.7/-72.6/-77.2
swath1	3/0/0	<b>32.6</b>	<b>1.7</b>	59.1	<b>13.2</b>	46.0/26.1/5.0/15.9
swath3	3/0/0	<b>49.3</b>	<b>2.6</b>	<b>74.3</b>	<b>18.6</b>	-32.7/-42.3/-42.3/-82.8
t1717	3/0/0	<b>118.0</b>	118.9	<b>54.5</b>	0.0	34.2/5.9/-20.2/0.0
tbfp-network	3/0/0	<b>37.3</b>	<b>17.6</b>	<b>22.1</b>	0.0	81.3/21.4/-36.7/0.0
thor50dday	3/0/0	<b>300.4</b>	<b>8.3</b>	<b>27.4</b>	<b>2.5</b>	-14.2/-13.3/-10.6/-32.0
timtab1	0/3/0	<b>41.2</b>	0.6	<b>94.0</b>	28.8	25.8/0.0/17.3/-3.1
timtab2	0/3/0	<b>82.3</b>	<b>9.8</b>	850.1	329.0	-10.6/-40.8/-6.9/-17.8
tr12-30	3/0/0	<b>48.5</b>	0.2	<b>43.1</b>	<b>7.0</b>	33.5/0.0/-26.5/-77.1
traininstance2	0/2/1	<b>110.3</b>	<b>5.3</b>	820.6	159.4	54.7/-37.7/-20.8/-57.0
traininstance6	0/3/0	<b>147.1</b>	<b>1.8</b>	390.6	69.3	68.1/-33.3/-21.7/-39.2
trento1	3/0/0	<b>136.3</b>	7.8	<b>7.1</b>	0.0	27.2/2.5/23.7/0.0
triptim1	0/3/0	0.1	22.5	3.9	0.0	0.0/3.4/2.5/0.0
uccase12	3/0/0	<b>3.1</b>	<b>11.7</b>	<b>18.6</b>	0.0	-38.7/-12.0/-16.1/0.0
uccase9	3/0/0	<b>1479.2</b>	<b>31.3</b>	95.3	35.4	73.6/45.9/49.7/51.5
uct-subprob	3/0/0	<b>16.4</b>	<b>0.4</b>	<b>9.7</b>	0.0	-24.4/33.3/-20.6/0.0
unitcal-7	0/0/3	<b>10.6</b>	<b>117.1</b>	852.4	46.5	60.4/15.0/14.0/68.1
var-smallemery-m6j6	3/0/0	<b>6.8</b>	25.9	74.6	<b>11.4</b>	97.3/-7.3/-9.5/-11.4
vpm2	3/0/0	43.6	0.1	<b>28.6</b>	<b>0.3</b>	3.1/0.0/-28.7/-100.0
wachplan	0/3/0	0.0	2.9	<b>40.2</b>	<b>0.3</b>	0.0/3.3/-34.1/-100.0
Geom. means			(270 instances)	(223 instances)		
FP		45.5	5.3	15.1	1.0	
FP+(5,1,h)		<b>41.5</b>	<b>6.2</b>	<b>18.5</b>	<b>1.6</b>	

Table A.14.: Performance of FP+(10,1,h)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	2/0/1	<b>1.8</b>	<b>6.7</b>	115.8	4.1	85.1/45.1/27.4/-70.7
30n20b8	0/0/3	<b>751.6</b>	<b>24.6</b>	856.7	323.6	-38.5/-76.8/-80.5/-91.1
50v-10	0/3/0	<b>147.7</b>	<b>0.4</b>	23.3	<b>0.6</b>	-15.6/-25.0/-1.3/-50.0

(continued)

Table A.14 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
CMS750-4	0/3/0	49.4	26.9	460.5	84.9	6.8/-84.8/-85.9/-85.9
a1c1s1	2/1/0	30.7	1.4	73.2	16.7	41.9/-71.4/-57.2/-92.2
academictimetablesmall	0/0/2	inf	578.9	1569.7	50.4	-/-/-/-
aflow30a	2/1/0	162.2	0.4	89.6	23.2	-18.9/-75.0/-62.6/-91.4
aflow40b	2/1/0	153.9	0.7	65.9	14.5	25.8/-57.1/-51.4/-89.7
air04	3/0/0	0.9	3.9	21.5	0.3	-88.9/-33.3/-69.3/-100.0
air05	3/0/0	3.1	1.5	16.7	0.0	24.4/-46.7/-76.0/0.0
app1-1	2/0/1	76.3	2.1	112.0	24.8	-95.9/-76.2/-69.1/-83.9
app1-2	0/0/3	11.6	206.6	1281.0	601.6	73.6/-94.8/-96.0/-97.5
arki001	0/0/3	1.7	27.3	1043.3	409.9	41.4/-24.2/-22.9/-54.5
assign1-5-8	3/0/0	1.9	0.1	24.9	0.0	0.0/0.0/-10.4/0.0
atlanta-ip	3/0/0	12.7	17.9	29.2	0.4	29.4/-5.6/-11.6/33.3
b1c1s1	0/2/1	213.3	14.2	291.7	121.8	-24.4/-96.5/-88.4/-97.0
bab2	0/1/2	8.4	964.4	884.4	138.8	67.1/-67.4/-80.4/-83.1
bab6	0/1/2	10.4	777.3	1173.1	250.2	56.1/-86.6/-92.5/-93.9
beasleyC3	1/2/0	12.9	0.7	116.0	41.6	-10.1/-71.4/-69.8/-88.5
binkar10-1	3/0/0	3.9	0.1	11.6	0.6	2.5/0.0/26.1/-100.0
blp-ar98	3/0/0	70.3	4.7	40.5	0.8	1.4/-57.4/-58.3/-100.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/3	0.0	172.8	1344.9	0.0	0.0/18.8/-37.0/0.0
bppc4-08	3/0/0	41.2	1.1	64.0	8.3	20.2/8.3/-2.7/10.8
brazil3	0/3/0	290.3	22.6	30.6	0.0	54.2/-6.6/-30.1/0.0
buildingenergy	0/3/0	1.1	601.2	11.0	0.0	0.0/13.7/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	inf	9.9	89.0	29.3	-100.0/-72.7/-55.1/-65.9
chromaticindex1024-7	3/0/0	0.0	54.6	2.3	0.0	0.0/0.4/23.3/0.0
chromaticindex512-7	3/0/0	0.0	45.1	2.0	0.0	0.0/-0.2/0.0/0.0
cmflsp50-24-8-8	1/0/2	14.8	85.2	668.0	252.8	24.1/49.1/36.4/14.2
co-100	3/0/0	302.0	6.8	17.5	0.0	0.3/-10.3/-10.9/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	3695.4	8.1	36.0	0.6	-7.3/-23.5/-33.3/-100.0
comp21-2idx	0/3/0	360.2	5.9	38.0	0.8	15.6/-22.0/-33.9/-100.0
cost266-UUE	3/0/0	32.9	0.5	32.5	1.3	6.3/-20.0/-27.7/-76.9
cryptanalysiskb128n5obj16	0/0/1	0.0	3228.9	764.0	0.0	-/-/-/-
csched007	0/0/3	27.7	10.2	883.2	176.6	59.9/-40.2/-56.7/-72.0
csched008	0/1/2	9.8	4.0	460.7	141.8	0.0/-57.5/-67.0/-83.1
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	18.3	18.0	0.0	0.0/2.1/-10.0/0.0
dano3-5	3/0/0	0.0	38.6	37.6	3.5	100.0/12.3/-19.9/-74.3
dano3mip	3/0/0	13.3	107.0	70.0	14.6	22.7/61.8/0.8/20.2
danooint	2/1/0	194.1	2.5	129.9	44.0	70.2/37.5/-14.2/-6.4
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	14.8	0.6	22.9	0.0	-62.2/-50.0/-43.2/0.0
drayage-25-23	3/0/0	10.9	0.9	35.6	1.6	-6.4/-55.6/-53.9/-100.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0
dws008-01	0/0/3	26.4	50.3	889.8	369.6	72.5/32.6/-7.9/-36.2
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0	0.0/0.0/0.0/0.0
enlight-hard	0/0/3	0.0	6.2	722.7	227.5	-/-/-/-
exp-1-500-5-5	3/0/0	55.7	0.1	34.9	2.4	26.1/0.0/-22.9/-100.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	736.4	0.3	21.1	0.0	18.8/25.0/-3.8/0.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	13.5	9.2	61.4	6.8	21.5/-23.9/-8.8/-32.4
fiber	3/0/0	160.5	0.1	16.3	0.0	-4.3/0.0/-8.6/0.0
fixnet6	3/0/0	56.4	0.1	31.0	1.0	-24.5/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	12.5	0.1	4.5	0.0	-16.0/0.0/-35.6/0.0
germanrr	0/3/0	8.3	36.3	250.9	61.7	-50.6/-67.8/-79.8/-90.4
gesa2	0/3/0	2.6	0.3	33.6	2.2	-7.7/-33.3/-39.3/-100.0
gesa2-o	0/3/0	23.5	1.1	106.2	18.3	-14.9/-81.8/-66.5/-91.8

(continued)

Table A.14 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	0/1/2	<b>1450.5</b>	<b>2.3</b>	834.6	385.9	-53.0/-87.0/-87.5/-91.7
gmu-35-40	3/0/0	6.9	0.1	14.0	0.0	-5.8/0.0/0.0/0.0
gmu-35-50	2/1/0	11.3	<b>1.1</b>	<b>104.7</b>	<b>24.8</b>	7.4/-72.7/-70.0/-96.0
graph20-20-1rand	3/0/0	<b>32.1</b>	<b>5.3</b>	<b>74.6</b>	<b>2.5</b>	-56.4/-22.6/-58.0/-84.0
graphdraw-domain	0/3/0	<b>267.8</b>	<b>1.2</b>	<b>223.7</b>	<b>69.6</b>	-89.2/-75.0/-72.9/-85.1
h80x6320d	3/0/0	24.4	<b>1.4</b>	<b>38.5</b>	<b>4.8</b>	-9.8/-14.3/-16.9/-60.4
harp2	3/0/0	11.9	0.1	12.3	0.0	4.0/0.0/3.1/0.0
highschool1-aigio	0/3/0	inf	<b>779.3</b>	<b>26.5</b>	0.0	0.0/-11.6/-42.3/0.0
hypothyroid-k1	3/0/0	0.0	4.7	1.0	0.0	0.0/2.1/0.0/0.0
ic97p	0/0/3	15.5	<b>8.0</b>	1031.3	447.0	-0.6/-36.3/-14.0/-54.0
ic97t	0/0/3	13.2	4.3	1257.2	446.4	-6.1/-9.3/0.7/-30.3
icir97p	0/0/3	<b>19.7</b>	<b>35.6</b>	993.9	277.0	14.0/-39.3/12.8/-22.1
icir97t	0/1/2	<b>11.1</b>	<b>56.2</b>	1150.4	535.6	29.3/-92.2/-81.7/-76.0
irish-electricity	2/1/0	6.4	<b>32.8</b>	<b>55.4</b>	<b>6.3</b>	-6.3/-40.9/-56.3/-95.2
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	33.3	6.8	<b>25.5</b>	0.0	7.5/-5.9/-13.7/0.0
k1mushroom	3/0/0	18.2	40.1	1.0	0.0	0.0/-0.7/0.0/0.0
lectsched-5-obj	0/0/3	<b>1836.0</b>	<b>161.3</b>	1474.9	1.5	18.2/-47.9/-38.4/78.6
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>866.0</b>	1.2	95.7	<b>34.9</b>	-22.1/-8.3/-6.0/38.3
lotsize	0/0/3	<b>306.1</b>	<b>9.7</b>	959.4	438.6	-76.9/-94.8/-95.3/-97.6
mad	3/0/0	<b>6502.0</b>	<b>0.2</b>	<b>18.6</b>	0.0	47.4/-50.0/-21.0/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>18.1</b>	50.2	<b>61.6</b>	<b>14.7</b>	59.5/-0.6/-41.9/-78.2
map16715-04	3/0/0	<b>54.9</b>	<b>66.1</b>	<b>60.0</b>	<b>14.6</b>	38.5/-13.9/-22.8/-37.7
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>155.0</b>	0.2	90.0	<b>9.6</b>	67.4/0.0/0.0/34.2
mas76	0/3/0	<b>155.6</b>	0.2	90.0	<b>10.8</b>	-32.0/0.0/0.8/49.8
mc11	0/3/0	<b>157.1</b>	<b>1.5</b>	<b>156.0</b>	<b>62.0</b>	-31.1/-73.3/-72.7/-80.2
mcsched	3/0/0	<b>20.2</b>	<b>0.6</b>	<b>4.3</b>	0.0	-36.1/-16.7/-16.3/0.0
mik-250-20-75-4	0/3/0	<b>24.3</b>	<b>0.3</b>	<b>20.6</b>	<b>1.7</b>	60.2/-33.3/46.2/62.2
milov12-6-r2-40-1	0/0/3	<b>106.6</b>	<b>19.1</b>	1151.7	555.8	29.1/-95.3/-96.4/-97.8
misc07	3/0/0	<b>22.9</b>	<b>0.3</b>	<b>52.5</b>	<b>0.8</b>	19.9/-66.7/-61.7/-100.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>21.4</b>	<b>0.4</b>	19.9	0.0	-34.6/-25.0/-1.5/0.0
modglob	3/0/0	<b>170.1</b>	0.1	33.6	<b>2.1</b>	-37.7/0.0/-6.8/-38.1
momentum1	0/0/3	<b>59.1</b>	<b>49.3</b>	726.3	342.3	69.4/-19.9/-23.2/3.1
msc98-ip	3/0/0	<b>10.7</b>	<b>8.2</b>	<b>47.7</b>	<b>5.5</b>	31.0/-23.2/-35.6/-89.1
mushroom-best	0/3/0	9.68e06	<b>61.5</b>	<b>119.8</b>	<b>6.0</b>	-5.3/-77.9/-66.6/-71.7
mzzv11	0/3/0	20.9	<b>7.6</b>	<b>53.5</b>	<b>4.1</b>	-3.8/-44.7/-63.9/-100.0
mzzv42z	0/3/0	<b>18.2</b>	<b>4.2</b>	26.2	<b>0.0</b>	41.3/14.3/-9.2/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	9.8	<b>0.5</b>	<b>34.3</b>	<b>2.6</b>	-4.1/-40.0/-40.5/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>3.3</b>	<b>6.1</b>	<b>38.0</b>	<b>4.6</b>	-72.7/-19.7/-30.5/-87.0
neos-1171737	3/0/0	<b>14.3</b>	<b>1.4</b>	<b>24.2</b>	<b>0.7</b>	-72.7/12.5/18.2/-14.3
neos-1354092	0/3/0	<b>7.5</b>	167.1	<b>54.0</b>	<b>0.3</b>	58.6/5.2/-30.4/-100.0
neos-1445765	3/0/0	<b>31.4</b>	<b>0.7</b>	5.5	0.0	11.3/12.5/1.8/0.0
neos-1456979	0/0/3	<b>78.7</b>	<b>81.8</b>	1125.3	77.7	47.5/-50.6/-58.9/19.5
neos-1582420	0/2/1	63.9	<b>11.3</b>	700.6	172.1	7.4/-86.7/-88.7/-94.5
neos-2657525-crna	0/3/0	960.7	0.2	41.3	<b>3.9</b>	5.5/0.0/1.2/-48.7
neos-2746589-doon	0/0/3	<b>8.5</b>	<b>252.8</b>	750.4	103.7	75.6/-45.4/-66.9/-69.8
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	2/1/0	<b>0.8</b>	<b>12.1</b>	<b>72.4</b>	<b>18.6</b>	-62.5/-21.5/-25.0/-20.4
neos-3004026-krka	0/0/3	0.0	<b>82.1</b>	810.8	4.0	0.0/24.7/36.9/-10.0

(continued)

Table A.14 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-3024952-loue	0/0/2	235.3	573.9	1743.6	0.0	-/-/-/-
neos-3046615-murg	0/3/0	<b>6840.3</b>	<b>1.5</b>	<b>503.5</b>	<b>107.4</b>	37.2/-86.7/-81.3/-38.9
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	124.6	<b>156.4</b>	992.0	126.0	-3.0/65.9/9.5/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>40.3</b>	999.9	0.0	0.0/-54.6/5.1/100.0
neos-3402294-bobin	2/1/0	<b>717.8</b>	<b>23.9</b>	<b>29.3</b>	<b>0.6</b>	-40.2/-15.9/-34.8/-100.0
neos-3555904-turama	2/1/0	2.0	<b>114.5</b>	<b>65.0</b>	<b>1.0</b>	0.0/-31.7/-51.7/-60.0
neos-3627168-kasai	3/0/0	<b>1.8</b>	0.1	20.4	0.0	-16.7/0.0/0.0/0.0
neos-3656078-kumeu	0/0/3	30.1	128.7	793.7	0.0	2.3/8.3/23.8/100.0
neos-3754480-nidda	3/0/0	<b>293.5</b>	0.2	68.3	<b>9.6</b>	19.7/0.0/-0.9/29.4
neos-4300652-rahue	0/0/3	<b>309.0</b>	<b>466.3</b>	803.6	1.2	-14.0/-11.5/-55.9/-75.0
neos-4338804-snowy	0/3/0	<b>71706.9</b>	<b>6.5</b>	<b>609.6</b>	<b>255.5</b>	37.1/-87.7/-83.5/-89.0
neos-4387871-tavua	0/0/3	<b>42.3</b>	<b>16.3</b>	714.0	333.9	94.4/28.8/11.0/21.9
neos-4413714-turia	3/0/0	<b>8.0</b>	<b>70.2</b>	<b>69.6</b>	<b>8.5</b>	81.8/12.1/12.7/34.6
neos-4532248-waihi	0/1/2	949.4	<b>431.9</b>	551.9	67.7	0.0/11.7/-20.3/-46.7
neos-4647030-tutaki	3/0/0	<b>12.7</b>	<b>31.8</b>	<b>35.8</b>	<b>3.1</b>	42.3/-45.0/-50.6/-100.0
neos-4722843-widden	0/2/1	<b>36.6</b>	<b>114.3</b>	193.7	49.4	81.5/-51.8/-52.3/-48.2
neos-4738912-atrato	0/3/0	<b>6.5</b>	<b>0.4</b>	<b>21.5</b>	0.0	45.8/-25.0/-42.3/0.0
neos-4763324-toguru	3/0/0	62.3	21.8	24.7	0.0	-5.0/-3.2/-4.0/0.0
neos-4954672-berkel	3/0/0	<b>77.9</b>	0.1	<b>37.3</b>	<b>4.2</b>	-29.8/0.0/-14.2/-69.0
neos-5049753-cuanza	0/1/2	<b>46.0</b>	<b>994.7</b>	491.3	118.7	39.2/-22.5/-33.7/-39.3
neos-5052403-cygnat	3/0/0	<b>0.6</b>	41.0	2.3	0.0	53.8/2.6/0.0/0.0
neos-5093327-huahum	3/0/0	<b>269.1</b>	<b>9.3</b>	115.7	<b>47.1</b>	70.5/30.6/4.1/45.6
neos-5104907-jarama	0/0/3	128.2	2285.2	1177.4	310.7	-/-/-/-
neos-5107597-kakapo	0/0/1	36348.4	23.3	1648.0	789.0	-/-/-/-
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	<b>4656.3</b>	<b>4.7</b>	26.3	0.0	-13.8/17.5/1.5/0.0
neos-5195221-niemur	2/1/0	<b>2209.9</b>	<b>8.4</b>	<b>24.4</b>	<b>0.3</b>	-65.3/-11.9/-23.4/-100.0
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	<b>321.5</b>	6.2	20.8	<b>0.6</b>	-30.6/3.1/-7.2/14.3
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>5.70e05</b>	99.2	68.3	<b>17.3</b>	-48.1/4.0/1.4/16.4
neos-860300	3/0/0	59.0	<b>0.5</b>	<b>6.0</b>	0.0	-3.4/-20.0/-33.3/0.0
neos-873061	3/0/0	60.6	<b>31.0</b>	<b>36.7</b>	<b>4.0</b>	1.0/-17.1/-13.6/-60.0
neos-911970	3/0/0	<b>221.1</b>	0.2	52.3	<b>2.6</b>	-40.3/0.0/-4.4/56.7
neos-933966	3/0/0	246.3	1.5	<b>11.7</b>	0.0	-9.0/6.3/-19.7/0.0
neos-950242	1/2/0	<b>79.4</b>	<b>34.0</b>	<b>109.5</b>	<b>10.7</b>	38.1/-80.3/-80.1/-96.3
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	1/1/1	<b>8.3</b>	<b>93.5</b>	370.6	32.7	-72.3/-78.4/-83.3/-93.6
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<b>0.6</b>	9.5	896.4	61.8	57.1/-2.1/23.3/-95.8
neos17	3/0/0	314.8	0.2	34.9	<b>2.7</b>	-7.8/0.0/-9.2/-40.7
neos20	0/0/3	<b>57.5</b>	9.6	995.8	126.1	-20.5/2.0/15.7/-35.4
neos5	3/0/0	<b>68.1</b>	0.1	<b>3.3</b>	0.0	-38.9/0.0/13.2/0.0
neos7	0/3/0	<b>8.3</b>	<b>0.8</b>	<b>65.5</b>	<b>7.9</b>	24.5/-75.0/-61.8/-100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>24.2</b>	<b>6.1</b>	<b>51.8</b>	<b>4.4</b>	36.8/-29.5/-50.4/-100.0
netdiversion	3/0/0	88.2	<b>67.3</b>	10.0	0.0	-2.0/10.1/-4.0/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	10.2	<b>19.9</b>	841.9	270.7	0.0/-31.7/22.9/-4.3
nh97t	0/0/3	<b>11.9</b>	<b>36.2</b>	1019.8	229.8	-10.9/-64.6/6.6/29.6
noswot	0/3/0	<b>14.0</b>	<b>0.3</b>	<b>89.0</b>	<b>12.8</b>	-31.4/-66.7/-61.5/-89.8
ns1116954	0/0/3	0.0	<b>1039.4</b>	1319.9	6.7	0.0/-54.6/-64.6/-52.2
ns1208400	2/0/1	0.0	<b>23.0</b>	159.6	1.2	0.0/74.5/59.6/-75.0
ns1644855	3/0/0	<b>17.0</b>	<b>567.6</b>	<b>65.3</b>	<b>15.7</b>	-97.1/-31.2/-47.2/-89.2
ns1760995	3/0/0	<b>23.1</b>	78.7	80.8	3.2	-35.5/7.0/-0.4/-9.4
ns1830653	1/0/2	<b>524.3</b>	<b>16.6</b>	515.6	21.1	-68.7/-73.5/-88.6/-95.3
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ipx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.1	<b>0.4</b>	20.5	0.0	6.1/-25.0/-7.3/0.0

(continued)

Table A.14 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
nursesched-medium-hint03	0/3/0	785.9	25.2	35.4	0.3	0.1/-44.8/-67.8/-100.0
nursesched-sprint02	0/3/0	55.2	3.0	17.6	0.0	0.0/-36.7/-47.2/0.0
nw04	3/0/0	8.9	3.5	13.9	0.0	-56.2/-42.9/-42.4/0.0
opm2-z10-s4	3/0/0	94.2	27.2	1.0	0.0	0.0/0.4/0.0/0.0
opt1217	3/0/0	0.0	0.2	47.7	5.1	100.0/-50.0/-23.9/-54.9
p200x1188c	3/0/0	4.4	0.2	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/3	0.0	460.0	1199.0	19.1	-/-/-/-
pg	2/1/0	6.2	0.4	72.4	17.8	60.0/-25.0/-28.6/7.3
pg5-34	3/0/0	1.3	0.3	52.3	10.7	81.7/25.0/-0.6/21.3
physiciansched3-3	0/1/2	703.1	131.2	484.9	134.6	-98.8/-58.5/-90.5/-99.3
physiciansched6-2	0/0/3	2.5	63.3	878.3	6.9	49.0/25.0/-15.7/80.2
piperout-08	0/0/3	175.1	73.3	1468.6	3.9	55.7/-5.6/14.2/88.3
piperout-27	0/0/3	135.0	76.2	1228.7	4.7	40.9/-13.4/-2.6/73.3
pk1	3/0/0	218.2	0.2	59.0	7.2	81.7/0.0/-1.7/19.1
pp08a	3/0/0	64.3	0.1	20.4	0.0	-9.2/0.0/-23.5/0.0
pp08aCUTS	3/0/0	65.5	0.1	27.2	0.3	-46.4/0.0/-55.9/-100.0
proteindesign121hz512p9	0/3/0	2.4	4.4	19.9	0.0	0.0/12.0/18.4/100.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	3/0/0	47.0	4.1	23.3	0.4	28.8/51.2/38.4/-100.0
qap10	3/0/0	19.4	13.7	2.0	0.0	0.0/0.0/0.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	241.5	0.8	39.0	1.0	-0.5/-37.5/-35.1/-100.0
rB10-011001	3/0/0	189.0	0.8	39.0	1.0	7.4/-37.5/-32.6/-100.0
rB11-010000	3/0/0	179.6	2.4	64.2	2.0	37.8/-45.8/-53.3/-70.0
rB11-110001	3/0/0	112.9	4.9	64.3	1.0	45.6/-46.9/-63.8/-70.0
rB12-111111	1/1/1	49.7	42.7	601.0	39.1	44.7/8.0/-4.4/-91.8
rC10-001000	3/0/0	114.6	0.8	82.3	1.9	58.3/-75.0/-66.1/-100.0
rC10-100001	3/0/0	708.5	7.6	156.0	0.0	-42.4/-35.5/-34.9/100.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	1/2/0	766.9	10.4	69.1	0.0	-58.0/-51.0/-47.3/100.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/2/1	226.8	47.3	963.6	158.6	-32.9/-96.2/-92.9/-97.7
radiationm40-10-02	0/3/0	1193.5	375.5	1606.5	75.1	-63.9/-95.7/-91.0/-88.0
rail01	3/0/0	32.7	1046.2	17.7	0.0	-5.2/18.3/-32.8/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.1	1.0	0.0	0.0/8.3/0.0/0.0
ran14x18-disj-8	3/0/0	24.0	0.3	21.2	0.0	-30.8/0.0/7.0/100.0
rd-rplusc-21	0/0/3	56.2	29.1	763.4	304.0	3.3/19.6/11.9/15.7
reblock115	1/0/2	8.1	8.9	377.5	111.3	27.7/-82.0/-85.3/-94.4
rmatr100-p10	3/0/0	17.7	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.1	2.0	0.0	0.0/0.0/0.0/0.0
rocl-4-11	0/0/3	71.6	23.6	964.7	274.6	-3.4/-10.2/-3.4/-62.2
rocll-5-11	0/0/3	90.6	60.3	1177.3	432.0	-0.2/-86.1/-86.7/-87.8
roi2alpha3n4	3/0/0	42.3	41.0	38.3	3.0	32.2/-18.8/-10.4/-46.7
roi5alpha10n8	3/0/0	65.3	657.2	39.3	2.3	-8.0/-32.0/-26.2/-100.0
roll3000	0/3/0	28.9	1.5	81.9	15.7	-9.3/-26.7/-40.9/-71.3
rout	0/3/0	46.1	0.6	169.2	60.4	6.9/-66.7/-79.2/-97.2
s100	3/0/0	2.8	240.6	4.0	0.0	-39.3/20.5/39.4/0.0
s250r10	3/0/0	0.1	53.3	2.0	0.0	0.0/0.2/0.0/0.0
satellites2-40	1/2/0	321.1	63.9	147.0	54.3	-23.6/-30.8/-76.3/-95.0
satellites2-60-fs	0/1/2	223.5	86.1	428.6	190.1	-60.0/-73.8/-91.9/-98.6
savsched1	0/3/0	9.5	207.0	13.6	0.0	-16.8/-8.2/-9.6/0.0
sct2	3/0/0	43.8	0.9	40.6	4.0	-33.3/-33.3/-35.7/-85.0
set1ch	3/0/0	48.1	0.1	31.7	1.3	43.8/0.0/-2.2/-23.1
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	8.7	2.9	8.6	0.0	-83.9/-6.9/-11.6/0.0
sing326	2/1/0	81.0	44.3	69.1	11.0	-86.9/-44.2/-50.8/-85.5
sing44	3/0/0	11.2	30.7	46.2	5.5	-33.9/-14.0/-16.7/-30.9
snp-02-004-104	0/3/0	11.8	26.7	43.9	6.0	-85.6/-26.2/-23.5/-68.3

(continued)

Table A.14 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	<b>36.7</b>	<b>4.0</b>	0.0/0.0/-14.7/-67.5
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.2	55.9	<b>8.0</b>	0.0	-0.6/10.0/38.5/0.0
square41	0/3/0	6.7	<b>1924.5</b>	<b>14.5</b>	0.0	0.0/-36.6/-31.0/0.0
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>193.3</b>	<b>126.6</b>	14.6	0.0	-11.9/-13.0/-6.8/0.0
supportcase12	0/3/0	<b>2.4</b>	<b>19.0</b>	<b>26.6</b>	0.0	-25.0/-23.2/-21.1/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	0/0/2	437.1	3.8	898.5	432.1	-/-/-/-
supportcase33	0/2/1	<b>75.0</b>	<b>30.6</b>	407.0	56.3	-14.0/-54.9/-70.2/-74.2
supportcase40	3/0/0	<b>52.9</b>	4.4	<b>22.6</b>	0.0	-66.7/-4.5/-26.5/0.0
supportcase42	0/3/0	<b>17.1</b>	<b>6.8</b>	<b>15.6</b>	0.0	29.9/-38.2/-25.6/0.0
supportcase6	3/0/0	<b>0.5</b>	14.2	<b>15.1</b>	0.0	-20.0/-6.3/-20.5/0.0
supportcase7	3/0/0	13.1	<b>9.8</b>	28.7	<b>0.6</b>	8.4/-15.3/-9.4/-100.0
swath	0/0/3	198.8	<b>41.6</b>	682.0	281.6	-8.7/-67.5/-72.5/-78.8
swath1	2/1/0	<b>70.4</b>	<b>3.8</b>	<b>100.0</b>	<b>29.8</b>	-14.2/-39.5/-37.8/-47.3
swath3	2/1/0	<b>80.3</b>	<b>4.0</b>	<b>100.7</b>	<b>30.5</b>	-58.7/-62.5/-57.4/-89.5
t1717	3/0/0	<b>83.1</b>	<b>150.2</b>	<b>75.1</b>	<b>0.3</b>	53.6/-15.9/-42.1/-100.0
tbfp-network	3/0/0	<b>34.6</b>	<b>13.3</b>	<b>15.8</b>	0.0	82.7/40.6/-11.4/0.0
thor50dday	3/0/0	<b>310.2</b>	<b>9.5</b>	<b>30.4</b>	<b>3.3</b>	-16.9/-24.2/-19.4/-48.5
timtab1	0/2/1	<b>64.0</b>	<b>3.5</b>	397.9	170.5	-13.3/-82.9/-71.4/-83.6
timtab2	0/0/3	69.3	<b>26.0</b>	1558.7	628.1	5.8/-77.7/-49.2/-56.9
tr12-30	1/2/0	74.1	<b>0.6</b>	<b>126.9</b>	<b>42.3</b>	-1.6/-66.7/-75.0/-96.2
traininstance2	0/1/2	<b>699.3</b>	3.4	485.1	130.6	-65.2/-2.9/25.3/-47.5
traininstance6	0/2/1	<b>39.9</b>	<b>1.4</b>	272.7	38.1	91.4/-14.3/10.9/9.5
trento1	3/0/0	<b>136.3</b>	7.8	<b>7.4</b>	0.0	27.2/2.5/20.4/0.0
triptim1	0/3/0	0.1	22.4	3.9	0.0	0.0/3.9/2.5/0.0
uccase12	3/0/0	<b>2.7</b>	<b>18.2</b>	<b>31.8</b>	<b>1.3</b>	-29.6/-43.4/-50.9/-100.0
uccase9	3/0/0	<b>441.6</b>	<b>29.8</b>	89.5	27.5	92.1/48.5/52.8/62.3
uct-subprob	3/0/0	<b>15.1</b>	<b>0.5</b>	<b>11.0</b>	0.0	-17.9/16.7/-30.0/0.0
unitcal-7	0/0/3	<b>11.6</b>	<b>99.7</b>	746.4	31.9	56.7/27.6/24.7/78.1
var-smallemergy-m6j6	3/0/0	<b>438.8</b>	<b>29.4</b>	<b>86.6</b>	<b>18.7</b>	-41.6/-18.4/-22.1/-46.0
vpm2	3/0/0	41.1	0.1	<b>32.3</b>	<b>1.6</b>	8.7/0.0/-36.8/-100.0
wachplan	0/3/0	0.0	<b>3.4</b>	<b>57.4</b>	<b>0.8</b>	0.0/-11.8/-53.8/-100.0
Geom. means		(269 instances)		(208 instances)		
FP		42.5	5.5	13.3	0.8	
FP+(10,l,h)		<b>41.9</b>	<b>7.3</b>	<b>18.3</b>	<b>1.6</b>	

Table A.15.: Performance of FP+(3,sd,g)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	1/1/1	<b>5.6</b>	<b>15.4</b>	257.7	15.7	53.7/-20.8/-38.1/-92.4
30n20b8	0/1/2	<b>291.7</b>	<b>23.9</b>	870.4	207.6	36.9/-76.2/-80.8/-86.1
50v-10	0/3/0	124.8	0.3	22.0	0.3	-0.1/0.0/4.3/0.0
CMS750-4	3/0/0	54.4	<b>6.1</b>	<b>101.7</b>	<b>14.5</b>	-2.6/-32.8/-36.0/-17.2
a1c1s1	3/0/0	<b>30.9</b>	<b>0.6</b>	31.7	<b>1.6</b>	41.5/-33.3/-1.3/-18.8
academictimetablesmall	0/0/2	inf	635.4	1153.0	0.7	-/-/-/-
aflow30a	3/0/0	<b>74.9</b>	0.1	34.2	<b>2.5</b>	43.1/0.0/-2.0/-20.0
aflow40b	3/0/0	<b>300.3</b>	<b>0.5</b>	<b>53.5</b>	<b>9.3</b>	-31.0/-40.0/-40.2/-83.9
air04	3/0/0	<b>0.4</b>	<b>3.1</b>	<b>8.8</b>	0.0	-75.0/-16.1/-25.0/0.0
air05	3/0/0	<b>3.1</b>	<b>1.7</b>	<b>16.1</b>	0.0	24.4/-52.9/-75.2/0.0
app1-1	3/0/0	<b>33.3</b>	<b>0.7</b>	<b>46.0</b>	<b>8.8</b>	-90.7/-28.6/-24.8/-54.5
app1-2	3/0/0	43.9	<b>13.6</b>	<b>65.9</b>	<b>23.4</b>	0.0/-21.3/-21.4/-34.6
arki001	0/3/0	3.1	<b>13.3</b>	648.8	165.9	-6.5/35.7/19.3/11.0
assign1-5-8	3/0/0	<b>2.6</b>	0.1	23.3	0.0	-26.9/0.0/-4.3/0.0

(continued)



Table A.15 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
atlanta-ip	3/0/0	<b>10.7</b>	16.3	<b>22.8</b>	<b>0.0</b>	40.6/3.6/11.6/100.0
b1c1s1	3/0/0	167.6	0.5	34.3	4.0	-3.8/0.0/-1.7/-10.0
bab2	0/0/3	<b>12.1</b>	<b>860.3</b>	788.4	210.4	52.5/-63.5/-78.1/-88.8
bab6	0/1/2	<b>21.3</b>	<b>397.7</b>	582.4	146.5	10.1/-73.7/-84.9/-89.6
beasleyC3	3/0/0	12.5	0.2	35.7	<b>5.6</b>	-7.2/0.0/-2.0/-14.3
binkar10-1	3/0/0	3.9	0.1	<b>7.7</b>	0.0	2.5/0.0/51.0/0.0
blp-ar98	3/0/0	69.9	2.2	17.9	0.0	2.0/-9.1/-5.6/0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/1	0.0	129.6	943.0	1.0	-/-/-/-
bppc4-08	3/0/0	<b>42.3</b>	1.1	62.3	9.7	18.0/8.3/0.0/-4.1
brazil3	0/3/0	<b>370.7</b>	22.7	<b>29.3</b>	0.0	41.6/-7.0/-27.0/0.0
buildingenergy	0/3/0	1.1	627.4	11.0	0.0	0.0/9.9/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.7	40.3	10.3	0.0/0.0/-0.7/-2.9
chromaticindex1024-7	3/0/0	0.0	54.0	<b>2.3</b>	0.0	0.0/1.5/23.3/0.0
chromaticindex512-7	3/0/0	0.0	45.1	2.0	0.0	0.0/-0.2/0.0/0.0
cmflsp50-24-8-8	1/1/1	18.9	<b>63.3</b>	452.5	152.9	3.1/62.2/56.9/48.1
co-100	3/0/0	<b>377.2</b>	<b>5.4</b>	14.3	0.0	-19.7/11.5/8.3/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	<b>4034.5</b>	6.1	24.0	0.0	-15.1/1.6/0.0/0.0
comp21-2idx	0/3/0	438.7	4.6	27.8	0.0	-2.7/0.0/-9.7/0.0
cost266-UUE	3/0/0	38.3	<b>0.5</b>	<b>29.9</b>	<b>0.6</b>	-8.4/-20.0/-21.4/-50.0
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/0/3	<b>52.1</b>	<b>12.7</b>	1059.3	205.6	24.5/-52.0/-63.9/-76.0
csched008	0/1/2	9.8	<b>4.4</b>	533.2	180.4	0.0/-61.4/-71.5/-86.7
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	18.6	17.7	0.0	0.0/0.5/-8.5/0.0
dano3-5	3/0/0	<b>0.1</b>	<b>104.0</b>	<b>45.7</b>	<b>7.2</b>	50.0/-57.7/-34.1/-87.5
dano3mip	3/0/0	<b>10.8</b>	<b>160.0</b>	70.3	<b>15.3</b>	37.2/42.9/0.4/16.4
danoint	1/2/0	<b>185.2</b>	<b>2.6</b>	<b>130.3</b>	<b>46.0</b>	71.6/35.0/-14.4/-10.4
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>7.5</b>	<b>0.4</b>	<b>15.2</b>	0.0	-25.3/-25.0/-14.5/0.0
drayage-25-23	3/0/0	<b>9.1</b>	<b>0.6</b>	<b>20.8</b>	0.0	10.8/-33.3/-21.2/0.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0
dws008-01	0/0/3	<b>32.9</b>	<b>96.2</b>	1544.1	545.1	65.7/-22.5/-46.9/-56.8
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.0	1.0	0.0	0.0/9.1/0.0/0.0
enlight-hard	0/0/2	0.0	3.0	719.0	212.6	-/-/-/-
exp-1-500-5-5	3/0/0	<b>136.7</b>	0.1	27.9	<b>0.3</b>	-44.8/0.0/-3.6/-100.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	929.1	0.4	<b>26.7</b>	<b>1.0</b>	-2.4/0.0/-24.0/-100.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>12.3</b>	7.4	55.0	4.8	28.5/-5.4/1.8/-4.2
fiber	3/0/0	153.6	0.1	15.7	0.0	0.0/0.0/-5.1/0.0
fixnet6	3/0/0	<b>53.9</b>	0.1	31.0	1.0	-21.0/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>12.5</b>	0.1	<b>4.5</b>	0.0	-16.0/0.0/-35.6/0.0
germanrr	0/3/0	4.1	<b>13.4</b>	<b>67.7</b>	<b>8.3</b>	0.0/-12.7/-25.0/-28.9
gesa2	0/3/0	2.4	0.2	20.4	0.0	0.0/0.0/0.0/0.0
gesa2-o	0/3/0	<b>10.0</b>	0.2	34.6	1.6	50.0/0.0/2.8/-6.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	<b>0.5</b>	1.0	0.0	0.0/16.7/0.0/0.0
glass4	3/0/0	<b>501.6</b>	0.3	<b>116.3</b>	<b>42.3</b>	26.4/0.0/-10.4/-23.9
gmu-35-40	3/0/0	6.5	0.1	14.6	0.0	0.0/0.0/-4.1/0.0
gmu-35-50	3/0/0	<b>9.5</b>	<b>0.4</b>	<b>43.4</b>	<b>3.2</b>	22.1/-25.0/-27.6/-68.8
graph20-20-1rand	3/0/0	<b>23.3</b>	4.3	<b>44.1</b>	<b>0.6</b>	-39.9/-4.7/-29.0/-33.3
graphdraw-domain	0/3/0	<b>258.3</b>	<b>0.6</b>	<b>137.4</b>	<b>48.6</b>	-88.9/-50.0/-55.8/-78.6
h80x6320d	3/0/0	21.0	1.2	32.0	1.9	4.5/0.0/0.0/0.0
harp2	3/0/0	12.1	0.1	12.7	0.0	2.4/0.0/0.0/0.0
highschool1-aigio	0/3/0	inf	<b>799.3</b>	<b>22.4</b>	0.0	0.0/-13.8/-31.7/0.0
hypothyroid-k1	3/0/0	0.0	4.6	1.0	0.0	0.0/4.2/0.0/0.0

(continued)

Table A.15 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
ic97p	0/2/1	<b>10.7</b>	<b>1.4</b>	193.8	73.0	30.5/72.5/78.1/64.5
ic97t	0/1/2	12.3	4.3	1295.6	449.2	0.8/-9.3/-2.3/-30.7
icir97p	0/0/3	<b>18.3</b>	20.0	839.1	218.1	20.1/7.4/26.4/-1.1
icir97t	0/2/1	<b>13.0</b>	<b>6.2</b>	233.4	127.8	17.2/-29.0/-9.8/0.8
irish-electricity	3/0/0	6.0	<b>25.6</b>	<b>34.7</b>	<b>1.5</b>	0.0/-24.2/-30.3/-80.0
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>18.3</b>	6.4	22.3	0.0	49.2/0.0/-1.3/0.0
k1mushroom	3/0/0	18.2	40.0	1.0	0.0	0.0/-0.5/0.0/0.0
lectsched-5-obj	0/0/3	<b>2691.7</b>	<b>126.5</b>	1324.5	0.3	-16.6/-33.6/-31.4/95.7
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>470.9</b>	1.2	89.7	57.3	30.2/-8.3/0.3/-1.2
lotsize	3/0/0	<b>59.0</b>	0.5	46.6	<b>11.9</b>	16.5/0.0/-3.6/-11.8
mad	3/0/0	<b>6322.9</b>	0.1	15.3	0.0	48.8/0.0/-3.9/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>26.3</b>	49.1	<b>50.4</b>	<b>6.1</b>	41.2/1.6/-29.0/-47.5
map16715-04	3/0/0	87.8	59.7	<b>54.5</b>	<b>10.9</b>	1.6/-4.7/-15.0/-16.5
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>622.3</b>	0.2	90.0	<b>12.5</b>	-23.5/0.0/0.0/14.4
mas76	0/3/0	<b>36.5</b>	0.2	90.0	<b>10.5</b>	65.5/0.0/0.8/51.2
mc11	3/0/0	97.5	0.4	42.3	12.3	9.9/0.0/0.7/0.0
mcsched	3/0/0	<b>15.6</b>	0.5	4.0	0.0	-17.3/0.0/-10.0/0.0
mik-250-20-75-4	0/3/0	<b>52.4</b>	0.2	<b>21.0</b>	<b>2.0</b>	14.2/0.0/45.2/55.6
milo-v12-6-r2-40-1	3/0/0	<b>124.2</b>	0.9	43.0	12.9	17.4/0.0/-2.3/-7.0
misc07	3/0/0	<b>51.6</b>	0.1	21.4	<b>0.3</b>	-44.6/0.0/-6.1/-100.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>9.7</b>	<b>0.4</b>	20.9	0.0	30.7/-25.0/-6.2/0.0
modglob	3/0/0	115.8	0.1	31.0	<b>1.0</b>	-8.5/0.0/1.0/23.1
momentum1	0/0/3	<b>170.1</b>	<b>74.7</b>	1035.7	542.3	12.0/-47.1/-46.1/-34.9
msc98-ip	3/0/0	<b>10.3</b>	6.2	31.0	<b>1.0</b>	33.5/1.6/-1.0/-40.0
mushroom-best	0/3/0	<b>1.57e06</b>	12.9	37.7	<b>1.3</b>	82.9/5.1/5.7/23.5
mzzv11	0/3/0	21.6	3.8	20.6	0.0	-6.9/9.5/-6.3/0.0
mzzv42z	0/3/0	<b>22.5</b>	<b>4.4</b>	24.3	<b>0.0</b>	27.4/10.2/-2.1/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>28.6</b>	<b>0.4</b>	<b>27.2</b>	<b>0.3</b>	-67.1/-25.0/-25.0/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>2.2</b>	5.3	<b>31.7</b>	<b>1.3</b>	-59.1/-7.5/-16.7/-53.8
neos-1171737	3/0/0	<b>4.4</b>	<b>1.8</b>	<b>33.7</b>	<b>2.6</b>	-11.4/-11.1/-12.2/-76.9
neos-1354092	0/3/0	<b>9.7</b>	183.8	<b>45.0</b>	<b>0.6</b>	46.4/-4.1/-16.4/-100.0
neos-1445765	3/0/0	<b>29.6</b>	<b>0.7</b>	5.8	0.0	16.4/12.5/-3.4/0.0
neos-1456979	0/2/1	<b>94.8</b>	<b>49.4</b>	682.0	126.3	36.8/-18.2/-32.2/-23.6
neos-1582420	0/2/1	74.5	<b>4.6</b>	290.2	50.1	-7.4/-67.4/-72.6/-81.2
neos-2657525-crna	0/3/0	999.9	0.2	40.6	<b>4.6</b>	1.6/0.0/2.9/-56.5
neos-2746589-doon	0/0/3	<b>7.6</b>	<b>462.4</b>	735.5	35.8	78.2/-70.1/-66.3/-12.6
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	1/2/0	<b>2.0</b>	<b>12.3</b>	<b>71.6</b>	<b>19.9</b>	-85.0/-22.8/-24.2/-25.6
neos-3004026-krka	0/0/3	0.0	<b>122.2</b>	1575.3	5.5	0.0/-10.8/-18.4/-34.5
neos-3024952-loue	0/0/2	941.7	180.9	1377.6	0.0	-/-/-/-
neos-3046615-murg	0/3/0	<b>12338.0</b>	0.2	95.9	64.4	-11.7/0.0/-1.7/1.8
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/1/2	131.4	<b>175.1</b>	1155.0	262.7	-8.0/61.8/-5.1/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>22.0</b>	836.7	0.0	0.0/-16.8/20.6/100.0
neos-3402294-bobin	2/1/0	<b>554.7</b>	<b>31.1</b>	<b>28.0</b>	<b>0.8</b>	-22.6/-35.4/-31.8/-100.0
neos-3555904-turama	1/2/0	<b>4.3</b>	<b>129.5</b>	<b>109.7</b>	<b>4.8</b>	-53.5/-39.6/-71.4/-91.7
neos-3627168-kasai	3/0/0	1.4	<b>0.2</b>	<b>27.2</b>	<b>0.3</b>	6.7/-50.0/-25.0/-100.0
neos-3656078-kumeu	0/0/3	32.7	<b>174.5</b>	1510.7	0.3	-5.8/-19.6/-31.1/66.7
neos-3754480-nidda	3/0/0	<b>6744.0</b>	0.2	67.7	<b>10.0</b>	-94.6/0.0/0.0/26.5
neos-4300652-rahue	0/2/1	<b>168.5</b>	<b>203.9</b>	188.0	1.2	36.6/50.6/47.0/-75.0

(continued)

Table A.15 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-4338804-snowy	0/3/0	<b>67829.1</b>	<b>1.0</b>	<b>115.0</b>	30.0	40.5/-20.0/-12.6/-6.7
neos-4387871-tavua	0/0/3	769.5	<b>19.3</b>	775.8	433.1	-1.9/15.7/3.3/-1.3
neos-4413714-turia	3/0/0	<b>125.2</b>	73.4	72.4	12.0	-64.9/8.1/9.2/7.7
neos-4532248-waihi	1/2/0	949.4	<b>281.3</b>	286.0	81.0	0.0/42.5/35.0/-55.4
neos-4647030-tutaki	3/0/0	<b>8.2</b>	<b>20.7</b>	<b>20.7</b>	0.0	62.7/-15.5/-14.5/0.0
neos-4722843-widden	0/3/0	<b>49.7</b>	55.2	98.2	<b>17.1</b>	74.9/-0.2/-5.9/33.2
neos-4738912-atrato	0/3/0	<b>7.7</b>	<b>0.4</b>	<b>21.5</b>	0.0	35.8/-25.0/-42.3/0.0
neos-4763324-toguru	3/0/0	55.6	21.2	23.3	0.0	6.1/-0.5/1.7/0.0
neos-4954672-berkel	3/0/0	<b>35.2</b>	0.1	34.0	<b>1.9</b>	35.6/0.0/-5.9/-31.6
neos-5049753-cuanza	0/2/1	<b>49.5</b>	<b>1096.8</b>	485.7	182.4	34.5/-29.8/-33.0/-60.5
neos-5052403-cygnat	3/0/0	<b>0.6</b>	41.0	2.3	0.0	53.8/2.6/0.0/0.0
neos-5093327-huahum	3/0/0	<b>226.0</b>	<b>8.8</b>	<b>90.9</b>	<b>55.1</b>	75.3/34.3/24.7/36.4
neos-5104907-jarama	0/0/3	98.5	2714.4	979.5	81.4	-/-/-/-
neos-5107597-kakapo	3/0/0	<b>16777.1</b>	1.7	125.0	92.5	57.3/5.6/-1.4/2.5
neos-5114902-kasavu	1/0/0	44.6	2470.0	96.0	20.0	-/-/-/-
neos-5188808-nattai	3/0/0	4341.3	<b>4.9</b>	25.6	0.0	-7.6/14.0/4.1/0.0
neos-5195221-niemur	3/0/0	805.1	<b>6.0</b>	<b>15.4</b>	0.0	-4.6/18.9/17.6/0.0
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	<b>308.3</b>	6.4	<b>22.1</b>	<b>2.3</b>	-27.6/0.0/-12.7/-69.6
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	3.21e05	104.7	71.6	19.9	-7.8/-1.3/-3.2/3.9
neos-860300	3/0/0	60.0	<b>0.5</b>	<b>6.0</b>	0.0	-5.0/-20.0/-33.3/0.0
neos-873061	3/0/0	<b>54.4</b>	27.6	32.0	<b>2.0</b>	11.1/-6.9/-0.9/-20.0
neos-911970	3/0/0	<b>155.0</b>	0.2	53.3	<b>3.5</b>	-14.8/0.0/-6.2/41.7
neos-933966	3/0/0	<b>197.6</b>	1.6	<b>11.7</b>	0.0	11.8/0.0/-19.7/0.0
neos-950242	2/1/0	<b>40.1</b>	<b>16.6</b>	<b>48.7</b>	<b>5.1</b>	68.7/-59.6/-55.2/-92.2
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	0/2/1	<b>9.6</b>	<b>122.5</b>	509.1	35.3	-76.0/-83.5/-87.8/-94.1
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<b>0.7</b>	9.9	1165.1	37.6	50.0/-6.1/0.3/-93.1
neos17	3/0/0	290.1	0.2	32.0	1.6	0.0/0.0/-0.9/0.0
neos20	0/1/2	<b>58.8</b>	<b>7.9</b>	869.6	73.1	-22.3/19.4/26.4/10.2
neos5	3/0/0	<b>74.8</b>	0.1	<b>3.3</b>	0.0	-44.4/0.0/13.2/0.0
neos7	0/3/0	<b>5.9</b>	0.2	<b>28.0</b>	0.0	46.4/0.0/-10.7/0.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>19.2</b>	3.9	23.4	0.0	49.9/9.3/8.9/0.0
netdiversion	3/0/0	81.9	<b>62.0</b>	<b>7.3</b>	0.0	5.2/17.2/24.0/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	<b>12.4</b>	12.5	716.1	185.6	-17.7/8.1/34.4/28.3
nh97t	0/0/3	<b>9.5</b>	<b>22.1</b>	1301.0	451.0	10.4/-42.1/-16.1/-27.6
noswot	0/3/0	<b>10.8</b>	0.1	<b>44.6</b>	<b>3.9</b>	-11.1/0.0/-23.1/-66.7
ns1116954	1/0/2	0.0	<b>394.2</b>	463.5	5.2	0.0/16.4/0.8/-38.5
ns1208400	2/1/0	0.0	<b>15.2</b>	<b>96.5</b>	0.3	0.0/83.1/75.6/0.0
ns1644855	3/0/0	<b>2.4</b>	<b>702.3</b>	<b>54.0</b>	<b>10.9</b>	-79.2/-44.4/-36.1/-84.4
ns1760995	3/0/0	<b>23.1</b>	<b>96.5</b>	<b>95.8</b>	<b>4.8</b>	-35.5/-12.3/-16.0/-39.6
ns1830653	0/1/2	<b>527.5</b>	<b>20.0</b>	533.5	27.3	-68.9/-78.0/-89.0/-96.3
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ipx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.4	0.3	18.6	0.0	-2.9/0.0/2.1/0.0
nursesched-medium-hint03	0/3/0	789.6	<b>20.1</b>	<b>24.0</b>	<b>0.4</b>	-0.4/-30.8/-52.5/-100.0
nursesched-sprint02	0/3/0	54.0	<b>2.6</b>	<b>14.5</b>	0.0	2.2/-26.9/-35.9/0.0
nw04	3/0/0	3.9	2.0	8.0	0.0	0.0/0.0/0.0/0.0
opm2-z10-s4	3/0/0	94.2	27.2	1.0	0.0	0.0/0.4/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	<b>0.2</b>	<b>46.3</b>	<b>7.0</b>	100.0/-50.0/-21.6/-67.1
p200x1188c	3/0/0	<b>4.4</b>	0.2	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/2	0.0	468.0	962.4	10.4	-/-/-/-
pg	3/0/0	<b>4.5</b>	0.3	52.0	<b>15.6</b>	71.0/0.0/-0.6/18.7
pg5-34	3/0/0	<b>2.9</b>	0.4	52.6	<b>11.3</b>	59.2/0.0/-1.1/16.9
physiciansched3-3	2/1/0	<b>117.1</b>	<b>67.0</b>	<b>103.2</b>	<b>6.0</b>	-92.6/-18.7/-55.4/-83.3

(continued)

Table A.15 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
physiciansched6-2	0/0/3	<b>2.8</b>	77.5	952.7	107.2	42.9/8.2/-22.3/-67.5
piperout-08	0/0/3	<b>107.0</b>	<b>44.1</b>	1066.8	49.1	72.9/36.3/37.6/-32.2
piperout-27	0/0/3	<b>188.2</b>	<b>43.0</b>	822.5	51.9	17.6/34.8/31.3/-66.1
pk1	3/0/0	<b>882.3</b>	0.2	<b>67.9</b>	8.8	26.0/0.0/-14.6/1.1
pp08a	3/0/0	<b>52.1</b>	0.1	<b>19.3</b>	0.0	10.8/0.0/-19.2/0.0
pp08aCUTS	3/0/0	<b>40.1</b>	0.1	<b>18.7</b>	0.0	-12.5/0.0/-35.8/0.0
proteindesign121hz512p9	0/3/0	2.4	<b>3.7</b>	<b>17.3</b>	<b>0.0</b>	0.0/26.0/29.1/100.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	2/1/0	67.7	<b>12.0</b>	<b>64.5</b>	<b>1.0</b>	-2.5/-30.0/-41.4/-100.0
qap10	3/0/0	19.4	13.7	2.0	0.0	0.0/0.0/0.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	<b>323.2</b>	0.5	23.5	0.0	-25.7/0.0/7.1/0.0
rB10-011001	3/0/0	<b>242.5</b>	<b>0.6</b>	25.1	<b>0.6</b>	-15.8/-16.7/4.6/-100.0
rB11-010000	3/0/0	<b>335.6</b>	<b>1.5</b>	29.2	0.6	-14.0/-13.3/2.7/0.0
rB11-110001	3/0/0	<b>148.3</b>	<b>3.9</b>	<b>39.0</b>	<b>1.0</b>	28.5/-33.3/-40.3/-70.0
rB12-111111	0/3/0	<b>78.2</b>	<b>59.2</b>	859.8	128.9	13.0/-21.6/-33.1/-97.5
rC10-001000	3/0/0	<b>194.1</b>	<b>0.3</b>	30.4	<b>0.8</b>	29.4/-33.3/-8.2/-100.0
rC10-100001	3/0/0	<b>455.4</b>	<b>5.9</b>	<b>121.2</b>	0.8	-10.3/-16.9/-16.3/0.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>204.8</b>	<b>10.6</b>	<b>78.4</b>	<b>1.1</b>	36.4/-51.9/-53.6/-27.3
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	155.5	<b>4.3</b>	<b>138.7</b>	<b>14.7</b>	-2.2/-58.1/-50.8/-75.5
radiationm40-10-02	0/3/0	<b>2091.8</b>	<b>36.0</b>	<b>317.6</b>	<b>30.2</b>	-79.4/-55.0/-54.7/-70.2
rail01	3/0/0	32.6	<b>1138.2</b>	<b>21.3</b>	0.0	-4.9/11.1/-44.1/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<b>24.8</b>	0.3	<b>20.4</b>	<b>0.0</b>	-33.1/0.0/10.5/100.0
rd-rplusc-21	0/0/3	58.4	35.7	916.0	383.5	-0.5/1.4/-5.4/-6.0
reblock115	3/0/0	<b>7.4</b>	<b>1.9</b>	<b>73.8</b>	<b>8.9</b>	33.9/-15.8/-24.9/-30.3
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.1	2.0	0.0	0.0/0.0/0.0/0.0
rocl-4-11	0/0/3	<b>82.1</b>	19.7	860.0	171.9	-15.7/7.1/7.7/-39.6
rocl-5-11	1/0/2	85.7	<b>22.5</b>	400.5	137.6	5.2/-62.7/-61.0/-61.8
roi2alpha3n4	3/0/0	<b>36.7</b>	34.1	33.3	<b>0.6</b>	41.2/-2.3/2.9/62.5
roi5alpha10n8	3/0/0	56.9	457.4	29.7	0.0	5.3/-2.4/-2.4/0.0
roll3000	0/3/0	<b>30.0</b>	<b>1.7</b>	<b>92.6</b>	<b>21.0</b>	-12.7/-35.3/-47.7/-78.6
rout	0/3/0	<b>43.4</b>	<b>0.1</b>	36.4	<b>2.1</b>	12.3/50.0/-3.3/-19.0
s100	3/0/0	<b>2.8</b>	<b>254.1</b>	<b>4.0</b>	0.0	-39.3/16.1/39.4/0.0
s250r10	3/0/0	0.1	53.3	2.0	0.0	0.0/0.2/0.0/0.0
satellites2-40	0/3/0	<b>310.9</b>	<b>70.1</b>	<b>147.0</b>	<b>57.0</b>	-21.1/-36.9/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>94.5</b>	410.2	182.7	-60.0/-76.1/-91.5/-98.5
savsched1	0/3/0	8.1	198.9	13.0	0.0	-2.5/-4.4/-5.4/0.0
sct2	3/0/0	30.3	<b>0.7</b>	<b>30.9</b>	<b>0.3</b>	-3.6/-14.3/-15.5/50.0
set1ch	3/0/0	<b>53.7</b>	0.1	31.0	1.0	37.3/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<b>8.8</b>	<b>3.2</b>	<b>9.2</b>	0.0	-84.1/-15.6/-17.4/0.0
sing326	3/0/0	<b>16.3</b>	<b>30.6</b>	<b>42.0</b>	<b>5.2</b>	-35.0/-19.3/-19.0/-69.2
sing44	3/0/0	<b>18.7</b>	<b>30.1</b>	<b>45.7</b>	<b>7.1</b>	-60.4/-12.3/-15.8/-46.5
snp-02-004-104	0/3/0	1.7	19.6	33.6	1.9	0.0/0.5/0.0/0.0
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.7	<b>1.6</b>	0.0/0.0/-1.3/-18.8
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.2	<b>54.7</b>	<b>8.0</b>	0.0	-0.6/11.9/38.5/0.0
square41	0/2/0	6.7	2624.4	19.9	0.0	-/-/-/-
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>131.0</b>	106.4	<b>12.0</b>	0.0	23.1/3.4/11.8/0.0
supportcase12	0/3/0	<b>2.1</b>	<b>18.6</b>	<b>25.2</b>	0.0	-14.3/-21.5/-16.7/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>5985.9</b>	0.2	90.0	59.7	36.2/0.0/-0.3/5.7

(continued)

Table A.15 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
supportcase33	0/3/0	<b>72.3</b>	<b>25.9</b>	<b>273.9</b>	<b>39.4</b>	-10.8/-46.7/-55.7/-63.2
supportcase40	3/0/0	<b>14.6</b>	4.0	17.3	0.0	17.0/4.8/-4.0/0.0
supportcase42	0/3/0	<b>14.3</b>	<b>5.3</b>	<b>14.1</b>	0.0	41.4/-20.8/-17.7/0.0
supportcase6	3/0/0	<b>3.0</b>	<b>15.8</b>	<b>16.3</b>	0.0	-86.7/-15.8/-26.4/0.0
supportcase7	3/0/0	<b>12.6</b>	8.9	26.0	0.0	11.9/-6.7/0.0/0.0
swath	0/0/3	<b>163.2</b>	<b>68.4</b>	684.0	281.3	10.1/-80.3/-72.5/-78.8
swath1	3/0/0	<b>26.6</b>	<b>1.8</b>	59.1	<b>13.2</b>	56.0/21.7/5.0/15.9
swath3	3/0/0	32.6	<b>2.1</b>	<b>63.3</b>	<b>14.9</b>	1.8/-28.6/-32.2/-78.5
t1717	1/2/0	<b>87.3</b>	<b>163.0</b>	<b>72.0</b>	<b>0.6</b>	51.3/-22.5/-39.6/-100.0
tbfp-network	3/0/0	<b>37.3</b>	<b>17.3</b>	<b>16.1</b>	0.0	81.3/22.8/-13.0/0.0
thor50dday	3/0/0	257.8	7.3	24.5	1.7	0.0/-1.4/0.0/0.0
timtab1	0/2/1	<b>73.3</b>	<b>1.3</b>	206.2	78.6	-24.3/-53.8/-44.9/-64.5
timtab2	0/1/2	78.6	<b>6.7</b>	669.7	344.7	-6.4/-13.4/15.4/-21.5
tr12-30	3/0/0	<b>46.9</b>	0.2	<b>40.2</b>	<b>6.3</b>	35.7/0.0/-21.1/-74.6
traininstance2	0/1/2	<b>648.4</b>	3.1	500.8	121.5	-62.4/6.1/22.9/-43.5
traininstance6	0/3/0	<b>25.4</b>	<b>0.4</b>	136.4	17.4	94.5/66.7/55.4/58.7
trento1	3/0/0	<b>268.5</b>	8.2	<b>10.9</b>	0.0	-30.3/-2.4/-14.7/0.0
triptim1	0/3/0	0.1	22.6	<b>4.6</b>	0.0	0.0/3.0/-13.0/0.0
uccase12	3/0/0	1.9	10.8	16.6	0.0	0.0/-4.6/-6.0/0.0
uccase9	3/0/0	<b>1445.5</b>	<b>31.9</b>	95.6	33.8	74.2/44.9/49.6/53.7
uct-subprob	3/0/0	<b>16.6</b>	<b>0.5</b>	<b>9.7</b>	0.0	-25.3/16.7/-20.6/0.0
unitcal-7	0/0/3	<b>16.4</b>	<b>105.4</b>	727.0	40.2	38.8/23.5/26.7/72.4
var-smallemerly-m6j6	3/0/0	<b>145.8</b>	25.7	74.0	<b>12.8</b>	43.1/-6.6/-8.8/-21.1
vpm2	3/0/0	<b>52.8</b>	0.1	<b>27.2</b>	<b>0.3</b>	-14.8/0.0/-25.0/-100.0
wachplan	0/3/0	0.0	3.1	<b>30.5</b>	0.0	0.0/-3.2/-13.1/0.0
Geom. means		(269 instances)	(221 instances)			
FP		45.5	5.2	14.8	1.0	
FP+(3,sd,g)		<b>43.0</b>	<b>5.7</b>	<b>16.6</b>	<b>1.3</b>	

Table A.16.: Performance of FP+(3,sv,g)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	1/1/1	<b>1.7</b>	<b>19.2</b>	270.9	21.6	86.0/-36.5/-41.1/-94.4
30n20b8	0/0/3	<b>739.0</b>	<b>26.8</b>	913.2	256.7	-37.5/-78.7/-81.7/-88.7
50v-10	0/3/0	130.5	<b>0.4</b>	<b>20.4</b>	<b>0.0</b>	-4.4/-25.0/11.3/100.0
CMS750-4	3/0/0	53.7	<b>6.4</b>	<b>97.8</b>	<b>13.7</b>	-1.3/-35.9/-33.4/-12.4
a1c1s1	3/0/0	<b>29.9</b>	<b>0.5</b>	31.7	<b>1.6</b>	43.4/-20.0/-1.3/-18.8
academictimetablesmall	0/0/2	inf	616.8	1382.6	74.5	-/-/-/-
aflow30a	3/0/0	<b>74.4</b>	0.1	32.0	<b>1.6</b>	43.5/0.0/4.5/20.0
aflow40b	3/0/0	<b>180.1</b>	0.3	34.2	<b>2.3</b>	13.1/0.0/-6.4/-34.8
air04	3/0/0	<b>0.4</b>	<b>2.9</b>	<b>8.8</b>	0.0	-75.0/-10.3/-25.0/0.0
air05	3/0/0	<b>3.1</b>	<b>1.6</b>	<b>16.1</b>	0.0	24.4/-50.0/-75.2/0.0
app1-1	3/0/0	<b>42.0</b>	<b>0.9</b>	<b>63.8</b>	<b>23.5</b>	-92.6/-44.4/-45.8/-83.0
app1-2	3/0/0	43.9	<b>18.0</b>	<b>79.8</b>	<b>33.5</b>	0.0/-40.6/-35.1/-54.3
arki001	0/3/0	2.8	<b>11.2</b>	635.9	152.6	3.4/45.9/20.9/18.1
assign1-5-8	3/0/0	<b>1.4</b>	0.1	23.7	0.0	26.3/0.0/-5.9/0.0
atlanta-ip	3/0/0	<b>11.7</b>	17.4	<b>32.2</b>	<b>0.3</b>	35.0/-2.9/-19.9/50.0
b1c1s1	3/0/0	<b>207.2</b>	0.5	34.7	4.0	-22.2/0.0/-2.9/-10.0
bab2	1/1/1	<b>14.9</b>	<b>407.2</b>	278.5	15.5	41.6/-22.9/-37.9/34.0
bab6	0/0/3	<b>14.7</b>	<b>494.8</b>	773.4	262.2	38.0/-78.9/-88.7/-94.2
beasleyC3	3/0/0	11.6	0.2	35.7	<b>5.6</b>	0.0/0.0/-2.0/-14.3
binkar10-1	3/0/0	3.9	0.1	<b>7.7</b>	0.0	2.5/0.0/51.0/0.0
blp-ar98	3/0/0	73.3	2.0	17.9	0.0	-2.7/0.0/-5.6/0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/0	-	-	-	-	-/-/-/-
bppc4-08	3/0/0	<b>31.5</b>	1.1	63.0	<b>7.1</b>	39.0/8.3/-1.1/23.7
brazil3	0/3/0	<b>490.2</b>	20.2	<b>25.6</b>	0.0	22.7/4.3/-16.4/0.0

(continued)

Table A.16 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
buildingenergy	0/3/0	1.1	721.6	11.0	0.0	0.0/-3.5/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.9	40.3	10.3	0.0/-6.9/-0.7/-2.9
chromaticindex1024-7	3/0/0	0.0	<b>63.0</b>	<b>2.3</b>	0.0	0.0/-13.0/23.3/0.0
chromaticindex512-7	3/0/0	0.0	42.9	2.0	0.0	0.0/4.7/0.0/0.0
cmflsp50-24-8-8	1/2/0	17.6	<b>29.9</b>	219.2	65.2	9.7/82.1/79.1/77.9
co-100	3/0/0	<b>377.2</b>	5.7	15.0	0.0	-19.7/6.6/3.8/0.0
cod105	3/0/0	100.0	1.9	1.0	0.0	0.0/-5.3/0.0/0.0
comp07-2idx	0/3/0	3673.0	5.7	<b>28.0</b>	0.0	-6.7/8.1/-14.3/0.0
comp21-2idx	0/3/0	408.3	<b>4.0</b>	27.8	0.0	4.4/13.0/-9.7/0.0
cost266-UUE	3/0/0	36.2	0.4	<b>28.3</b>	0.3	-3.0/0.0/-17.0/0.0
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/1/2	<b>49.9</b>	<b>16.0</b>	1420.0	339.8	27.7/-61.9/-73.1/-85.5
csched008	2/1/0	9.8	<b>2.4</b>	<b>243.2</b>	<b>52.7</b>	0.0/-29.2/-37.5/-54.5
cvs16r128-89	3/0/0	97.9	0.9	1.0	0.0	0.0/10.0/0.0/0.0
dano3-3	3/0/0	0.0	<b>16.8</b>	16.9	0.0	0.0/10.2/-4.1/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>94.2</b>	<b>45.4</b>	<b>6.9</b>	-33.3/-53.3/-33.7/-87.0
dano3mip	3/0/0	<b>12.3</b>	<b>148.3</b>	71.6	<b>16.0</b>	28.5/47.1/-1.4/12.6
danooint	1/2/0	651.4	3.6	<b>201.7</b>	<b>86.2</b>	0.0/10.0/-44.7/-52.2
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>6.6</b>	<b>0.4</b>	<b>15.2</b>	0.0	-15.2/-25.0/-14.5/0.0
drayage-25-23	3/0/0	<b>14.6</b>	<b>0.7</b>	<b>26.4</b>	<b>0.3</b>	-30.1/-42.9/-37.9/-100.0
ds	3/0/0	4945.0	6.3	1.0	0.0	0.0/-4.8/0.0/0.0
dws008-01	0/0/3	<b>59.5</b>	<b>95.5</b>	1351.9	440.4	38.0/-21.9/-39.4/-46.5
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0	0.0/0.0/0.0/0.0
enlight-hard	0/0/3	0.0	3.5	720.3	195.7	-/-/-/-
exp-1-500-5-5	3/0/0	<b>139.2</b>	0.1	27.2	<b>0.3</b>	-45.8/0.0/-1.1/-100.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	928.7	0.4	<b>26.4</b>	<b>1.0</b>	-2.3/0.0/-23.1/-100.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>10.4</b>	6.5	52.3	<b>3.4</b>	39.5/7.1/6.6/26.1
fiber	3/0/0	142.9	0.1	<b>19.3</b>	0.0	7.0/0.0/-22.8/0.0
fixnet6	3/0/0	39.1	0.1	31.0	1.0	8.2/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>12.5</b>	0.1	<b>4.5</b>	0.0	-16.0/0.0/-35.6/0.0
germanrr	0/3/0	<b>8.7</b>	<b>17.6</b>	<b>105.3</b>	<b>17.6</b>	-52.9/-33.5/-51.8/-66.5
gesa2	0/3/0	2.4	0.2	20.4	0.0	0.0/0.0/0.0/0.0
gesa2-o	0/3/0	<b>8.6</b>	0.2	34.6	1.6	57.0/0.0/2.8/-6.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	<b>0.5</b>	1.0	0.0	0.0/16.7/0.0/0.0
glass4	1/2/0	<b>1049.0</b>	<b>0.4</b>	<b>166.7</b>	<b>65.8</b>	-35.0/-25.0/-37.5/-51.1
gmu-35-40	3/0/0	6.5	0.1	<b>15.9</b>	0.0	0.0/0.0/-11.9/0.0
gmu-35-50	3/0/0	11.3	<b>0.4</b>	<b>44.7</b>	<b>3.3</b>	7.4/-25.0/-29.8/-69.7
graph20-20-1rand	3/0/0	<b>22.4</b>	3.9	<b>42.8</b>	<b>0.8</b>	-37.5/4.9/-26.9/-50.0
graphdraw-domain	0/3/0	<b>180.8</b>	<b>0.6</b>	<b>129.6</b>	<b>42.4</b>	-84.1/-50.0/-53.2/-75.5
h80x6320d	3/0/0	20.9	1.1	32.0	1.9	5.0/8.3/0.0/0.0
harp2	3/0/0	11.3	0.1	12.3	0.0	8.9/0.0/3.1/0.0
highschool1-aigio	0/3/0	inf	<b>1077.9</b>	<b>36.9</b>	<b>0.3</b>	0.0/-36.1/-58.5/-100.0
hypothyroid-k1	3/0/0	0.0	5.0	1.0	0.0	0.0/-4.0/0.0/0.0
ic97p	0/2/1	<b>12.2</b>	<b>1.7</b>	244.1	84.3	20.8/66.7/72.5/59.0
ic97t	0/0/3	11.9	<b>4.5</b>	1265.0	432.5	4.0/-13.3/0.1/-28.0
icir97p	0/0/3	<b>19.0</b>	22.1	844.1	197.0	17.0/-2.3/25.9/8.7
icir97t	0/3/0	<b>8.3</b>	<b>3.8</b>	<b>132.7</b>	<b>65.4</b>	47.1/13.6/37.0/49.2
irish-electricity	3/0/0	5.7	<b>23.4</b>	<b>21.6</b>	<b>0.0</b>	5.0/-17.1/10.7/100.0
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>10.4</b>	<b>5.7</b>	21.7	0.0	71.1/10.9/1.4/0.0
k1mushroom	3/0/0	18.2	40.3	1.0	0.0	0.0/-1.2/0.0/0.0
lectsched-5-obj	0/0/3	<b>2736.6</b>	<b>138.2</b>	1516.4	9.1	-17.9/-39.2/-40.1/-23.1
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.16 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
liu	3/0/0	<b>470.9</b>	1.0	89.7	57.3	30.2/9.1/0.3/-1.2
lotsize	3/0/0	76.5	0.5	<b>49.9</b>	<b>12.4</b>	-7.6/0.0/-10.0/-15.3
mad	3/0/0	<b>6322.9</b>	0.1	14.7	0.0	48.8/0.0/0.0/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>36.6</b>	48.3	<b>64.6</b>	<b>17.3</b>	18.1/3.2/-44.6/-81.5
map16715-04	3/0/0	<b>100.0</b>	54.0	<b>56.4</b>	<b>11.6</b>	-10.8/5.1/-17.9/-21.6
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>329.6</b>	0.2	90.0	<b>9.0</b>	30.7/0.0/0.0/38.4
mas76	0/3/0	<b>94.1</b>	0.2	90.0	<b>11.1</b>	11.1/0.0/0.8/48.4
mc11	3/0/0	102.9	<b>0.6</b>	42.3	12.3	4.9/-33.3/0.7/0.0
mcsched	3/0/0	<b>14.7</b>	<b>0.6</b>	4.0	0.0	-12.2/-16.7/-10.0/0.0
mik-250-20-75-4	0/3/0	66.3	<b>0.1</b>	<b>15.1</b>	<b>0.9</b>	-7.8/50.0/60.6/80.0
milo-v12-6-r2-40-1	3/0/0	<b>124.2</b>	1.0	43.0	12.9	17.4/-10.0/-2.3/-7.0
misc07	3/0/0	<b>22.8</b>	<b>0.2</b>	<b>16.5</b>	0.0	20.3/-50.0/17.9/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>5.0</b>	<b>0.4</b>	<b>23.7</b>	0.0	64.3/-25.0/-17.3/0.0
modglob	3/0/0	117.6	0.1	31.3	1.3	-9.9/0.0/0.0/0.0
momentum1	0/0/3	178.9	<b>81.2</b>	1126.4	568.0	7.5/-51.4/-50.5/-37.8
mssc98-ip	3/0/0	<b>11.0</b>	6.4	33.5	<b>1.3</b>	29.0/-1.6/-8.4/-53.8
mushroom-best	0/3/0	<b>1.75e06</b>	12.7	42.6	<b>1.3</b>	80.9/6.6/-6.1/23.5
mzzv11	0/3/0	20.4	<b>3.7</b>	<b>22.0</b>	0.0	-1.5/11.9/-12.3/0.0
mzzv42z	0/3/0	<b>21.1</b>	<b>3.6</b>	21.6	<b>0.0</b>	31.9/26.5/9.2/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>12.4</b>	<b>0.5</b>	<b>27.2</b>	<b>0.3</b>	-24.2/-40.0/-25.0/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>5.3</b>	<b>4.2</b>	<b>31.3</b>	<b>1.3</b>	-83.0/14.3/-15.7/-53.8
neos-1171737	3/0/0	3.6	1.6	<b>33.0</b>	<b>2.6</b>	7.7/0.0/-10.3/-76.9
neos-1354092	0/3/0	<b>8.3</b>	<b>141.5</b>	36.2	0.0	54.1/19.7/3.7/0.0
neos-1445765	3/0/0	<b>30.7</b>	<b>0.7</b>	<b>6.6</b>	0.0	13.3/12.5/-15.2/0.0
neos-1456979	0/3/0	<b>110.2</b>	<b>23.3</b>	317.7	74.8	26.5/42.3/31.3/22.5
neos-1582420	0/3/0	<b>77.5</b>	<b>4.0</b>	<b>236.4</b>	<b>37.8</b>	-11.0/-62.5/-66.4/-75.1
neos-2657525-crna	0/3/0	960.9	<b>0.1</b>	41.2	<b>2.3</b>	5.5/50.0/1.4/-13.0
neos-2746589-doon	0/0/3	<b>7.6</b>	<b>610.6</b>	704.3	25.5	78.2/-77.4/-64.8/18.5
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	1/2/0	<b>2.0</b>	<b>11.8</b>	<b>71.6</b>	<b>19.9</b>	-85.0/-19.5/-24.2/-25.6
neos-3004026-krka	0/0/3	0.0	<b>162.9</b>	1886.1	4.5	0.0/-33.1/-31.8/-20.0
neos-3024952-loue	0/0/3	882.8	<b>182.7</b>	1516.1	0.4	-7.9/-56.3/-6.7/98.6
neos-3046615-murg	0/3/0	<b>7902.9</b>	<b>0.1</b>	94.8	63.4	27.5/50.0/-0.5/3.4
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	133.7	<b>169.7</b>	1142.8	289.8	-9.6/63.0/-4.1/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>34.3</b>	1271.7	0.6	0.0/-46.6/-17.1/45.5
neos-3402294-bobin	3/0/0	<b>642.3</b>	<b>46.5</b>	<b>47.3</b>	<b>2.3</b>	-33.2/-56.8/-59.6/-100.0
neos-3555904-turama	1/2/0	<b>4.3</b>	<b>120.3</b>	<b>72.3</b>	<b>0.6</b>	-53.5/-35.0/-56.6/-33.3
neos-3627168-kasai	3/0/0	<b>1.7</b>	0.1	20.4	0.0	-11.8/0.0/0.0/0.0
neos-3656078-kumeu	0/0/3	<b>27.7</b>	<b>160.8</b>	1299.4	0.0	10.1/-12.7/-19.8/100.0
neos-3754480-nidda	3/0/0	<b>226.1</b>	<b>0.3</b>	67.3	<b>10.0</b>	38.2/-33.3/0.6/26.5
neos-4300652-rahue	0/0/3	<b>315.9</b>	<b>505.9</b>	749.4	1.4	-15.9/-18.4/-52.7/-78.6
neos-4338804-snowy	0/3/0	<b>46700.7</b>	<b>1.5</b>	<b>135.2</b>	<b>40.1</b>	59.0/-46.7/-25.7/-30.2
neos-4387871-tavua	0/1/2	<b>885.9</b>	<b>20.4</b>	765.2	391.9	-14.8/10.9/4.6/8.3
neos-4413714-turia	3/0/0	<b>3.4</b>	83.4	73.9	<b>11.1</b>	92.3/-4.2/7.3/14.6
neos-4532248-waihi	0/1/2	949.4	<b>981.0</b>	1131.3	135.0	0.0/-50.2/-61.1/-73.3
neos-4647030-tutaki	3/0/0	<b>8.2</b>	<b>19.9</b>	<b>20.7</b>	0.0	62.7/-12.1/-14.5/0.0
neos-4722843-widden	0/3/0	<b>20.0</b>	55.3	86.0	<b>17.0</b>	89.9/-0.4/6.9/33.6
neos-4738912-atrato	0/3/0	<b>6.9</b>	<b>0.4</b>	<b>21.5</b>	0.0	42.5/-25.0/-42.3/0.0
neos-4763324-toguru	3/0/0	54.3	22.8	25.4	0.0	8.3/-7.5/-6.7/0.0
neos-4954672-berkel	3/0/0	<b>31.1</b>	0.1	34.3	<b>2.8</b>	43.1/0.0/-6.7/-53.6
neos-5049753-cuanza	0/2/1	<b>49.3</b>	<b>1055.9</b>	412.8	126.3	34.8/-27.0/-21.1/-43.0
neos-5052403-cygnat	3/0/0	<b>0.6</b>	44.8	2.3	0.0	53.8/-6.0/0.0/0.0

(continued)

Table A.16 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-5093327-huahum	3/0/0	823.2	<b>10.1</b>	<b>98.2</b>	<b>62.9</b>	9.9/24.6/18.6/27.4
neos-5104907-jarama	0/0/2	53.3	2467.2	934.8	175.8	-/-/-/-
neos-5107597-kakapo	3/0/0	<b>16401.3</b>	1.7	127.3	93.8	58.3/5.6/-3.1/1.2
neos-5114902-kasavu	1/1/0	38.2	2547.4	112.2	31.4	-/-/-/-
neos-5188808-nattai	3/0/0	4181.2	<b>4.3</b>	25.9	0.0	-4.0/24.6/3.0/0.0
neos-5195221-niemur	3/0/0	769.3	6.8	19.8	0.0	-0.2/8.1/-5.6/0.0
neos-631710	3/0/0	149.4	2.5	1.0	0.0	0.0/0.0/0.0/0.0
neos-662469	0/3/0	<b>341.3</b>	<b>5.6</b>	<b>15.7</b>	<b>0.0</b>	-34.6/12.5/18.7/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>277.7</b>	<b>79.3</b>	<b>53.1</b>	<b>11.4</b>	99.9/23.2/23.4/44.9
neos-860300	3/0/0	<b>64.9</b>	<b>0.6</b>	<b>6.0</b>	0.0	-12.2/-33.3/-33.3/0.0
neos-873061	3/0/0	59.3	26.8	31.7	1.6	3.1/-4.1/0.0/0.0
neos-911970	3/0/0	134.6	0.2	53.3	<b>4.8</b>	-1.9/0.0/-6.2/20.0
neos-933966	3/0/0	<b>157.7</b>	<b>1.3</b>	9.8	0.0	29.6/18.8/-4.1/0.0
neos-950242	3/0/0	123.3	<b>10.5</b>	<b>30.6</b>	<b>1.2</b>	3.9/-36.2/-28.8/-66.7
neos-957323	3/0/0	6.6	2.0	1.9	0.0	0.0/4.8/0.0/0.0
neos-960392	1/1/1	<b>10.9</b>	<b>60.1</b>	259.6	10.8	-78.9/-66.4/-76.2/-80.6
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<b>0.8</b>	<b>8.3</b>	992.6	29.2	42.9/10.8/15.1/-91.1
neos17	3/0/0	306.3	0.2	32.0	1.6	-5.3/0.0/-0.9/0.0
neos20	0/0/3	<b>61.9</b>	10.8	1238.6	103.5	-26.2/-9.3/-4.6/-21.4
neos5	3/0/0	<b>80.6</b>	0.1	<b>3.3</b>	0.0	-48.4/0.0/13.2/0.0
neos7	0/3/0	11.1	0.2	<b>28.5</b>	<b>0.4</b>	-0.9/0.0/-12.3/-100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>19.2</b>	<b>3.8</b>	26.7	0.0	49.9/11.6/-3.7/0.0
netdiversion	3/0/0	81.9	<b>65.4</b>	<b>7.1</b>	0.0	5.2/12.7/26.0/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	9.8	13.3	805.1	262.9	3.9/2.2/26.3/-1.5
nh97t	0/0/3	10.6	<b>20.0</b>	1277.5	340.4	0.0/-36.0/-14.5/-4.1
noswot	0/3/0	<b>5.8</b>	0.1	<b>40.9</b>	<b>4.0</b>	39.6/0.0/-16.1/-67.5
ns1116954	0/0/3	0.0	<b>1273.3</b>	1345.3	14.2	0.0/-62.9/-65.3/-77.5
ns1208400	1/1/1	0.0	<b>48.0</b>	261.2	0.3	0.0/46.7/34.0/0.0
ns1644855	3/0/0	<b>1.9</b>	<b>720.1</b>	<b>48.2</b>	<b>6.7</b>	-73.7/-45.8/-28.4/-74.6
ns1760995	3/0/0	14.1	85.3	74.0	<b>2.3</b>	5.4/-0.8/8.1/20.7
ns1830653	0/0/3	<b>528.6</b>	<b>34.7</b>	973.2	106.8	-68.9/-87.3/-94.0/-99.1
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ixp	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.4	0.3	18.6	0.0	-2.9/0.0/2.1/0.0
nursesched-medium-hint03	0/3/0	754.5	<b>17.6</b>	<b>20.1</b>	0.0	4.1/-21.0/-43.3/0.0
nursesched-sprint02	0/3/0	52.1	<b>2.5</b>	<b>13.3</b>	0.0	5.6/-24.0/-30.1/0.0
nw04	3/0/0	3.9	2.2	<b>9.0</b>	0.0	0.0/-9.1/-11.1/0.0
opm2-z10-s4	3/0/0	94.2	27.9	1.0	0.0	0.0/-2.2/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	0.1	<b>47.3</b>	<b>7.0</b>	100.0/0.0/-23.3/-67.1
p200x1188c	3/0/0	<b>4.4</b>	0.2	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/-
pg	3/0/0	<b>4.3</b>	0.3	52.3	<b>15.0</b>	72.3/0.0/-1.1/21.9
pg5-34	3/0/0	<b>2.6</b>	0.4	52.0	<b>11.6</b>	63.4/0.0/0.0/14.7
physiciansched3-3	2/1/0	<b>45.3</b>	<b>68.7</b>	<b>89.1</b>	<b>6.4</b>	-80.8/-20.7/-48.4/-84.4
physiciansched6-2	0/0/3	<b>3.9</b>	79.5	911.4	61.3	20.4/5.8/-18.8/-43.2
piperout-08	0/0/3	<b>67.7</b>	<b>44.3</b>	1000.4	41.7	82.9/36.0/41.5/-20.1
piperout-27	0/0/3	<b>43.7</b>	<b>43.5</b>	837.1	54.4	80.9/34.1/30.1/-67.6
pk1	3/0/0	<b>567.3</b>	0.2	<b>68.8</b>	8.2	52.4/0.0/-15.7/7.9
pp08a	3/0/0	<b>33.6</b>	0.1	<b>19.9</b>	0.0	42.5/0.0/-21.6/0.0
pp08aCUTS	3/0/0	<b>9.5</b>	0.1	<b>19.6</b>	0.0	72.9/0.0/-38.8/0.0
proteindesign121hz512p9	0/3/0	2.4	<b>4.5</b>	22.5	<b>0.0</b>	0.0/10.0/7.8/100.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	3/0/0	<b>57.6</b>	<b>6.3</b>	34.4	<b>0.8</b>	12.7/25.0/9.0/-100.0
qap10	3/0/0	19.4	13.7	2.0	0.0	0.0/0.0/0.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0

(continued)



Table A.16 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
rB10-011000	3/0/0	<b>294.1</b>	<b>0.6</b>	<b>29.2</b>	<b>0.6</b>	-18.3/-16.7/-13.4/-100.0
rB10-011001	3/0/0	<b>231.5</b>	0.5	27.0	0.0	-11.8/0.0/-2.6/0.0
rB11-010000	3/0/0	<b>252.3</b>	<b>1.6</b>	<b>37.0</b>	<b>1.0</b>	12.6/-18.8/-18.9/-40.0
rB11-110001	3/0/0	<b>146.4</b>	<b>3.2</b>	<b>32.0</b>	<b>0.0</b>	29.4/-18.8/-27.2/100.0
rB12-111111	1/2/0	<b>71.9</b>	<b>23.6</b>	323.7	19.0	20.0/49.1/43.7/-83.2
rC10-001000	3/0/0	<b>172.6</b>	<b>0.3</b>	29.7	<b>0.3</b>	37.3/-33.3/-6.1/-100.0
rC10-100001	3/0/0	416.3	<b>5.6</b>	112.4	<b>1.3</b>	-1.9/-12.5/-9.7/-38.5
rC11-010100	3/0/0	347.0	<b>0.3</b>	1.0	0.0	0.0/-33.3/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>364.1</b>	<b>5.8</b>	<b>42.9</b>	<b>1.0</b>	-11.6/-12.1/-15.2/-20.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>309.7</b>	<b>3.2</b>	<b>113.8</b>	<b>14.8</b>	-50.9/-43.8/-40.0/-75.7
radiationm40-10-02	0/3/0	<b>1740.1</b>	<b>41.3</b>	<b>364.8</b>	<b>37.2</b>	-75.2/-60.8/-60.6/-75.8
rail01	3/0/0	32.6	1171.5	<b>18.5</b>	0.0	-4.9/8.5/-35.7/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	<b>1.0</b>	1.0	0.0	0.0/16.7/0.0/0.0
ran14x18-disj-8	3/0/0	<b>22.9</b>	0.3	22.8	0.3	-27.5/0.0/0.0/0.0
rd-rplusc-21	0/0/3	56.2	38.4	892.6	375.8	3.3/-5.7/-2.9/-4.0
reblock115	2/1/0	<b>8.8</b>	<b>5.0</b>	<b>194.5</b>	<b>33.1</b>	21.4/-68.0/-71.5/-81.3
rmatr100-p10	3/0/0	<b>17.7</b>	<b>0.5</b>	2.3	0.0	40.0/16.7/0.0/0.0
rmatr200-p5	3/0/0	19.5	13.5	2.0	0.0	0.0/4.3/0.0/0.0
rocl-4-11	0/0/3	<b>57.0</b>	<b>25.1</b>	1073.3	235.1	17.6/-15.5/-13.2/-55.8
rocll-5-11	0/1/2	<b>72.7</b>	<b>36.6</b>	679.9	219.6	19.6/-77.0/-77.0/-76.0
roi2alpha3n4	3/0/0	<b>41.1</b>	<b>37.7</b>	36.2	<b>2.4</b>	34.1/-11.7/-5.2/-33.3
roi5alpha10n8	3/0/0	57.7	<b>593.0</b>	<b>34.6</b>	<b>1.1</b>	4.0/-24.7/-16.2/-100.0
roll3000	0/3/0	<b>34.2</b>	1.0	50.6	<b>5.8</b>	-23.4/9.1/-4.3/-22.4
rout	0/3/0	<b>32.3</b>	0.2	38.1	<b>2.2</b>	34.7/0.0/-7.6/-22.7
s100	3/0/0	<b>2.8</b>	<b>271.7</b>	<b>4.0</b>	0.0	-39.3/10.2/39.4/0.0
s250r10	3/0/0	0.1	58.2	2.0	0.0	0.0/-8.2/0.0/0.0
satellites2-40	0/3/0	<b>357.9</b>	<b>70.4</b>	<b>147.0</b>	<b>57.0</b>	-31.4/-37.2/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>90.1</b>	410.6	182.9	-60.0/-74.9/-91.5/-98.5
savshed1	0/3/0	<b>9.6</b>	190.7	13.0	0.0	-17.7/-0.3/-5.4/0.0
sct2	3/0/0	<b>58.7</b>	<b>0.8</b>	<b>35.9</b>	<b>1.9</b>	-50.3/-25.0/-27.3/-68.4
set1ch	3/0/0	<b>98.8</b>	0.1	31.0	1.0	-13.4/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<b>1.1</b>	2.7	7.7	0.0	21.4/0.0/-1.3/0.0
sing326	3/0/0	<b>12.2</b>	<b>29.7</b>	<b>42.2</b>	<b>5.2</b>	-13.1/-16.8/-19.4/-69.2
sing44	3/0/0	<b>11.9</b>	27.8	<b>45.0</b>	<b>6.8</b>	-37.8/-5.0/-14.4/-44.1
snp-02-004-104	0/3/0	1.7	20.0	33.6	1.9	0.0/-1.5/0.0/0.0
sorrell3	3/0/0	76.3	<b>0.8</b>	1.0	0.0	0.0/11.1/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.7	<b>1.6</b>	0.0/0.0/-1.3/-18.8
sp97ar	3/0/0	28.5	<b>0.8</b>	2.2	0.0	-6.7/11.1/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	98.2	<b>69.1</b>	<b>15.0</b>	0.0	0.4/-10.1/-13.3/0.0
square41	0/2/0	6.7	2877.8	19.9	0.0	-/-/-/-
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>120.5</b>	110.5	<b>12.0</b>	0.0	29.2/-0.4/11.8/0.0
supportcase12	0/3/0	<b>2.3</b>	<b>16.4</b>	<b>24.5</b>	0.0	-21.7/-11.0/-14.3/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>5985.9</b>	<b>0.3</b>	90.0	59.7	36.2/-33.3/-0.3/5.7
supportcase33	0/3/0	62.8	<b>24.8</b>	<b>240.4</b>	<b>49.6</b>	2.6/-44.4/-49.5/-70.8
supportcase40	3/0/0	16.7	4.2	18.3	0.0	5.1/0.0/-9.3/0.0
supportcase42	0/3/0	<b>14.3</b>	<b>5.5</b>	<b>14.1</b>	0.0	41.4/-23.6/-17.7/0.0
supportcase6	3/0/0	<b>0.5</b>	14.3	<b>13.5</b>	0.0	-20.0/-7.0/-11.1/0.0
supportcase7	3/0/0	<b>12.6</b>	8.9	26.0	0.0	11.9/-6.7/0.0/0.0
swath	0/1/2	183.5	<b>71.0</b>	698.6	281.4	-1.0/-81.0/-73.1/-78.8
swath1	3/0/0	<b>12.2</b>	<b>2.0</b>	62.2	15.0	79.8/13.0/0.0/4.5
swath3	3/0/0	<b>24.6</b>	<b>2.3</b>	<b>60.6</b>	<b>14.5</b>	25.9/-34.8/-29.2/-77.9
t1717	2/1/0	<b>96.3</b>	<b>164.5</b>	<b>78.9</b>	<b>0.3</b>	46.3/-23.2/-44.9/-100.0
tbfp-network	3/0/0	<b>45.9</b>	20.9	<b>22.2</b>	0.0	77.0/6.7/-36.9/0.0
thor50dday	3/0/0	257.8	7.2	24.5	1.7	0.0/0.0/0.0/0.0

(continued)

Table A.16 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
timtab1	0/3/0	59.5	<b>0.4</b>	<b>67.0</b>	<b>22.6</b>	-6.7/33.3/41.1/19.0
timtab2	0/2/1	74.9	<b>3.8</b>	352.3	142.8	-1.7/34.5/55.5/47.2
tr12-30	3/0/0	<b>51.4</b>	0.2	<b>40.0</b>	<b>6.5</b>	29.5/0.0/-20.8/-75.4
traininstance2	0/0/3	<b>135.3</b>	<b>6.4</b>	1097.8	216.3	44.5/-48.4/-40.8/-68.3
traininstance6	0/2/1	<b>293.5</b>	<b>1.0</b>	235.8	44.9	36.4/16.7/22.9/-6.2
trento1	3/0/0	<b>330.0</b>	8.6	<b>11.9</b>	0.0	-43.3/-7.0/-21.8/0.0
triptim1	0/3/0	0.1	22.2	<b>4.6</b>	0.0	0.0/4.7/-13.0/0.0
uccase12	3/0/0	<b>1.7</b>	10.0	15.8	0.0	10.5/2.9/-1.3/0.0
uccase9	3/0/0	<b>1465.6</b>	<b>35.8</b>	103.9	38.6	73.9/38.2/45.2/47.1
uct-subprob	3/0/0	13.7	<b>0.5</b>	<b>9.3</b>	0.0	-9.5/16.7/-17.2/0.0
unitcal-7	1/0/2	25.9	<b>61.3</b>	426.6	64.0	3.4/55.5/57.0/56.1
var-smalllemery-m6j6	3/0/0	<b>20.9</b>	25.6	73.3	<b>13.6</b>	91.8/-6.3/-7.9/-25.7
vpm2	3/0/0	42.4	0.1	<b>27.2</b>	<b>0.3</b>	5.8/0.0/-25.0/-100.0
wachplan	0/3/0	0.0	<b>3.5</b>	<b>38.3</b>	<b>0.4</b>	0.0/-14.3/-30.8/-100.0
Geom. means		(270 instances)	(224 instances)			
FP		46.0	5.3	15.2	1.1	
FP+(3,sv,g)		<b>40.1</b>	<b>5.8</b>	<b>17.2</b>	<b>1.4</b>	

Table A.17.: Performance of FP+(3,sd,h)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	3/0/0	<b>2.0</b>	<b>1.5</b>	<b>18.7</b>	1.2	83.5/87.7/88.3/0.0
30n20b8	0/1/2	449.2	<b>20.0</b>	721.3	181.2	2.8/-71.5/-76.8/-84.1
50v-10	0/3/0	<b>143.6</b>	0.3	22.0	0.3	-13.2/0.0/4.3/0.0
CMS750-4	3/0/0	<b>62.9</b>	<b>6.5</b>	<b>108.0</b>	<b>15.7</b>	-15.7/-36.9/-39.7/-23.6
a1c1s1	3/0/0	<b>25.8</b>	<b>0.6</b>	31.7	<b>1.6</b>	51.1/-33.3/-1.3/-18.8
academictimetablesmall	0/0/3	inf	548.9	1272.8	17.0	-/-/-/-
aflow30a	3/0/0	<b>69.4</b>	0.1	36.6	<b>3.7</b>	47.3/0.0/-8.5/-45.9
aflow40b	3/0/0	224.0	<b>0.4</b>	<b>44.1</b>	<b>5.8</b>	-7.5/-25.0/-27.4/-74.1
air04	3/0/0	<b>0.8</b>	<b>3.6</b>	<b>17.8</b>	0.0	-87.5/-27.8/-62.9/0.0
air05	3/0/0	<b>3.1</b>	<b>1.6</b>	<b>16.1</b>	0.0	24.4/-50.0/-75.2/0.0
app1-1	3/0/0	<b>42.0</b>	<b>0.8</b>	<b>50.5</b>	<b>11.2</b>	-92.6/-37.5/-31.5/-64.3
app1-2	3/0/0	43.9	<b>17.2</b>	<b>84.3</b>	<b>35.1</b>	0.0/-37.8/-38.6/-56.4
arki001	0/2/1	2.9	<b>25.3</b>	1152.1	284.4	0.0/-18.2/-30.2/-34.5
assign1-5-8	3/0/0	<b>1.5</b>	0.1	24.2	0.0	21.1/0.0/-7.9/0.0
atlanta-ip	3/0/0	<b>12.1</b>	<b>15.1</b>	<b>20.3</b>	<b>0.0</b>	32.8/10.7/21.3/100.0
b1c1s1	3/0/0	162.2	<b>0.6</b>	<b>37.6</b>	<b>5.5</b>	-0.6/-16.7/-10.4/-34.5
bab2	0/0/3	<b>17.5</b>	<b>941.6</b>	882.6	183.7	31.4/-66.6/-80.4/-87.2
bab6	0/1/2	<b>21.3</b>	<b>425.2</b>	660.4	109.1	10.1/-75.4/-86.7/-86.0
beasleyC3	3/0/0	11.4	0.2	35.7	<b>5.6</b>	1.7/0.0/-2.0/-14.3
binkar10-1	3/0/0	3.9	0.1	<b>7.7</b>	0.0	2.5/0.0/51.0/0.0
blp-ar98	3/0/0	69.6	2.1	17.9	0.0	2.4/-4.8/-5.6/0.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/2	0.0	156.8	809.7	0.0	-/-/-/-
bppc4-08	3/0/0	<b>226.9</b>	1.1	60.9	8.9	-77.3/8.3/2.2/4.3
brazil3	0/3/0	<b>191.4</b>	<b>18.0</b>	23.3	0.0	69.8/14.7/-8.2/0.0
buildingenergy	0/3/0	1.1	627.1	11.0	0.0	0.0/10.0/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.8	40.7	10.7	0.0/-3.6/-1.7/-6.5
chromaticindex1024-7	3/0/0	0.0	54.0	<b>2.3</b>	0.0	0.0/1.5/23.3/0.0
chromaticindex512-7	3/0/0	0.0	45.2	2.0	0.0	0.0/-0.4/0.0/0.0
cmflsp50-24-8-8	2/0/1	19.0	<b>51.3</b>	367.4	127.6	2.6/69.4/65.0/56.7
co-100	3/0/0	302.2	6.1	15.6	0.0	0.2/0.0/0.0/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	3610.3	6.5	26.5	0.0	-5.1/-4.6/-9.4/0.0
comp21-2idx	0/3/0	431.3	4.7	26.7	0.0	-1.0/-2.1/-6.0/0.0
cost266-UUE	3/0/0	<b>40.9</b>	<b>0.5</b>	<b>29.5</b>	<b>0.6</b>	-14.2/-20.0/-20.3/-50.0

(continued)

Table A.17 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
cryptanalysisk128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/1/2	<b>39.4</b>	<b>8.9</b>	814.0	168.3	42.9/-31.5/-53.0/-70.6
csched008	2/1/0	9.0	<b>1.3</b>	<b>121.4</b>	<b>16.7</b>	8.2/23.5/20.1/30.4
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	18.1	<b>18.0</b>	0.0	0.0/3.2/-10.0/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>109.0</b>	<b>47.3</b>	<b>7.5</b>	-33.3/-59.6/-36.4/-88.0
dano3mip	3/0/0	<b>13.4</b>	<b>146.7</b>	72.3	<b>14.3</b>	22.1/47.6/-2.4/21.9
danooint	1/2/0	651.4	<b>2.9</b>	<b>152.2</b>	<b>61.9</b>	0.0/27.5/-26.7/-33.4
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>17.8</b>	<b>0.6</b>	<b>22.9</b>	0.0	-68.5/-50.0/-43.2/0.0
drayage-25-23	3/0/0	10.9	<b>0.7</b>	<b>24.1</b>	0.0	-6.4/-42.9/-32.0/0.0
ds	3/0/0	4945.0	6.0	1.0	0.0	0.0/0.0/0.0/0.0
dws008-01	0/1/2	<b>35.9</b>	<b>63.5</b>	942.4	334.2	62.6/14.9/-13.0/-29.5
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.0	1.0	0.0	0.0/9.1/0.0/0.0
enlight-hard	0/0/2	0.0	3.1	702.2	201.5	-/-/-/-
exp-1-500-5-5	3/0/0	<b>60.4</b>	0.1	28.3	<b>0.3</b>	19.9/0.0/-4.9/-100.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>642.9</b>	<b>0.3</b>	20.0	0.0	29.1/25.0/1.5/0.0
fhnw-binpack4-48	0/0/2	0.0	74.2	1611.3	166.0	-/-/-/-
fiball	0/3/0	<b>12.2</b>	7.0	53.3	<b>3.7</b>	29.1/0.0/4.8/19.6
fiber	3/0/0	153.6	0.1	15.7	0.0	0.0/0.0/-5.1/0.0
fixnet6	3/0/0	<b>53.0</b>	0.1	31.0	1.0	-19.6/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>12.5</b>	0.1	<b>4.5</b>	0.0	-16.0/0.0/-35.6/0.0
germanrr	0/3/0	4.3	<b>16.1</b>	<b>84.4</b>	<b>13.6</b>	-4.7/-27.3/-39.8/-56.6
gesa2	0/3/0	2.4	0.2	20.4	0.0	0.0/0.0/0.0/0.0
gesa2-o	0/3/0	<b>10.0</b>	0.2	34.6	1.6	50.0/0.0/2.8/-6.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	3/0/0	<b>525.8</b>	<b>0.4</b>	<b>145.3</b>	<b>61.1</b>	22.8/-25.0/-28.3/-47.3
gmu-35-40	3/0/0	6.5	0.1	14.6	0.0	0.0/0.0/-4.1/0.0
gmu-35-50	3/0/0	<b>6.2</b>	<b>0.4</b>	<b>41.4</b>	<b>2.9</b>	49.2/-25.0/-24.2/-65.5
graph20-20-1rand	3/0/0	<b>33.3</b>	<b>4.9</b>	<b>53.1</b>	<b>1.5</b>	-58.0/-16.3/-41.1/-73.3
graphdraw-domain	0/3/0	<b>118.7</b>	<b>0.5</b>	<b>97.8</b>	<b>26.0</b>	-75.7/-40.0/-37.9/-60.0
h80x6320d	3/0/0	21.4	1.2	32.3	<b>2.3</b>	2.7/0.0/-0.9/-17.4
harp2	3/0/0	12.1	0.1	12.7	0.0	2.4/0.0/0.0/0.0
highschool1-aigio	0/3/0	inf	<b>1151.7</b>	<b>43.4</b>	<b>0.3</b>	0.0/-40.2/-64.7/-100.0
hypothyroid-k1	3/0/0	0.0	4.6	1.0	0.0	0.0/4.2/0.0/0.0
ic97p	0/2/1	<b>12.3</b>	<b>2.2</b>	294.8	90.3	20.1/56.9/66.8/56.0
ic97t	0/0/3	13.1	4.1	1280.7	449.0	-5.3/-4.9/-1.1/-30.7
icir97p	0/0/3	<b>20.2</b>	<b>24.2</b>	1101.1	270.5	11.8/-10.7/3.4/-20.3
icir97t	0/3/0	<b>13.9</b>	<b>7.5</b>	<b>280.8</b>	<b>156.6</b>	11.5/-41.3/-25.0/-17.8
irish-electricity	3/0/0	<b>7.1</b>	<b>28.5</b>	<b>46.2</b>	<b>5.0</b>	-15.5/-31.9/-47.6/-94.0
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>16.7</b>	6.5	23.3	0.0	53.6/-1.5/-5.6/0.0
k1mushroom	3/0/0	18.2	39.9	1.0	0.0	0.0/-0.3/0.0/0.0
lectsched-5-obj	0/0/3	2402.6	<b>112.5</b>	1111.3	0.4	-6.5/-25.3/-18.2/94.3
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	674.7	1.2	89.7	56.6	0.0/-8.3/0.3/0.0
lotsize	3/0/0	72.8	0.5	48.1	<b>12.9</b>	-2.9/0.0/-6.7/-18.6
mad	3/0/0	<b>6322.9</b>	0.1	15.3	0.0	48.8/0.0/-3.9/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>33.6</b>	52.5	<b>73.0</b>	<b>21.0</b>	24.8/-5.0/-51.0/-84.8
map16715-04	3/0/0	<b>99.7</b>	60.7	<b>56.7</b>	<b>11.6</b>	-10.5/-6.3/-18.3/-21.6
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>1233.3</b>	0.2	90.0	<b>12.5</b>	-61.4/0.0/0.0/14.4
mas76	0/3/0	<b>173.7</b>	0.2	90.0	<b>9.5</b>	-39.1/0.0/0.8/55.8

(continued)

Table A.17 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
mc11	3/0/0	105.6	0.4	43.3	13.0	2.4/0.0/-1.6/-5.4
mcsched	3/0/0	<b>16.1</b>	<b>0.6</b>	4.0	0.0	-19.9/-16.7/-10.0/0.0
mik-250-20-75-4	0/3/0	<b>51.9</b>	0.2	<b>21.0</b>	<b>2.0</b>	15.1/0.0/45.2/55.6
milo-v12-6-r2-40-1	3/0/0	<b>110.0</b>	0.9	42.3	12.3	26.8/0.0/-0.7/-2.4
misc07	3/0/0	<b>20.8</b>	<b>0.2</b>	<b>25.9</b>	0.0	27.3/-50.0/-22.4/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>22.7</b>	<b>0.4</b>	21.7	0.0	-38.3/-25.0/-9.7/0.0
modglob	3/0/0	106.9	0.1	31.3	1.3	-0.9/0.0/0.0/0.0
momentum1	0/0/2	152.4	58.2	752.8	394.9	-/-/-/-
msc98-ip	3/0/0	<b>11.6</b>	6.7	<b>34.9</b>	<b>1.7</b>	25.2/-6.0/-12.0/-64.7
mushroom-best	0/3/0	9.56e06	<b>20.2</b>	<b>54.1</b>	<b>1.3</b>	-4.1/-32.7/-26.1/23.5
mzzv11	0/3/0	21.7	<b>4.7</b>	<b>29.7</b>	<b>1.2</b>	-7.4/-10.6/-35.0/-100.0
mzzv42z	0/3/0	<b>23.3</b>	<b>4.0</b>	22.0	<b>0.0</b>	24.8/18.4/7.6/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>26.5</b>	<b>0.4</b>	<b>30.3</b>	<b>0.6</b>	-64.5/-25.0/-32.7/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>2.6</b>	5.4	<b>32.7</b>	<b>2.0</b>	-65.4/-9.3/-19.3/-70.0
neos-1171737	3/0/0	<b>4.6</b>	1.7	28.1	<b>1.9</b>	-15.2/-5.9/5.1/-68.4
neos-1354092	0/3/0	<b>4.6</b>	180.9	<b>42.9</b>	0.0	74.6/-2.5/-12.4/0.0
neos-1445765	3/0/0	<b>31.8</b>	0.8	<b>6.4</b>	0.0	10.2/0.0/-12.5/0.0
neos-1456979	0/2/1	<b>90.5</b>	<b>76.7</b>	951.8	102.7	39.6/-47.3/-51.4/-6.0
neos-1582420	0/3/0	<b>79.9</b>	<b>6.1</b>	<b>357.0</b>	<b>51.5</b>	-13.6/-75.4/-77.7/-81.7
neos-2657525-crna	0/3/0	987.7	<b>0.3</b>	<b>54.4</b>	<b>7.1</b>	2.8/-33.3/-23.2/-71.8
neos-2746589-doon	0/0/3	<b>7.1</b>	<b>395.2</b>	706.3	23.8	79.7/-65.1/-64.9/24.0
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	1/2/0	<b>2.2</b>	<b>12.1</b>	<b>69.8</b>	<b>19.1</b>	-86.4/-21.5/-22.2/-22.5
neos-3004026-krka	0/0/3	0.0	114.1	1416.3	4.6	0.0/-4.5/-9.2/-21.7
neos-3024952-loue	0/0/3	<b>914.2</b>	<b>202.8</b>	1855.9	0.0	-11.1/-60.6/-23.8/100.0
neos-3046615-murg	0/3/0	<b>1357.7</b>	0.2	95.2	63.8	87.5/0.0/-0.9/2.7
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/1/2	<b>135.4</b>	<b>122.8</b>	843.8	225.6	-10.7/73.2/23.0/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>20.5</b>	929.5	0.0	0.0/-10.7/11.8/100.0
neos-3402294-bobin	3/0/0	<b>609.5</b>	<b>35.4</b>	<b>39.6</b>	<b>2.0</b>	-29.6/-43.2/-51.8/-100.0
neos-3555904-turama	3/0/0	2.0	<b>67.5</b>	<b>19.8</b>	<b>0.0</b>	0.0/13.7/36.9/100.0
neos-3627168-kasai	3/0/0	1.5	0.1	20.4	0.0	0.0/0.0/0.0/0.0
neos-3656078-kumeu	0/0/3	31.9	<b>160.0</b>	1226.9	0.0	-3.4/-12.3/-15.1/100.0
neos-3754480-nidda	3/0/0	<b>7.3</b>	0.2	67.3	<b>10.3</b>	98.0/0.0/0.6/24.3
neos-4300652-rahue	0/1/2	245.8	<b>309.8</b>	352.5	1.2	7.5/25.0/0.6/-75.0
neos-4338804-snowy	0/3/0	<b>55542.6</b>	<b>0.9</b>	105.3	30.8	51.3/-11.1/-4.6/-9.1
neos-4387871-tavua	0/0/3	<b>886.1</b>	22.0	861.5	469.9	-14.8/3.9/-6.9/-9.0
neos-4413714-turia	3/0/0	<b>2.8</b>	<b>69.4</b>	<b>66.6</b>	<b>9.6</b>	93.6/13.1/16.4/26.2
neos-4532248-waihi	1/0/2	949.4	444.6	478.9	154.4	0.0/9.1/-8.2/-76.6
neos-4647030-tutaki	3/0/0	<b>5.4</b>	<b>29.8</b>	<b>32.3</b>	<b>1.6</b>	75.5/-41.3/-45.2/-100.0
neos-4722843-widden	0/3/0	<b>51.6</b>	55.2	96.1	23.6	73.9/-0.2/-3.9/7.8
neos-4738912-atrato	0/3/0	<b>6.4</b>	<b>0.5</b>	<b>22.5</b>	0.0	46.7/-40.0/-44.9/0.0
neos-4763324-toguru	3/0/0	55.6	20.9	23.3	0.0	6.1/0.9/1.7/0.0
neos-4954672-berkel	3/0/0	<b>32.0</b>	0.1	<b>35.6</b>	<b>3.2</b>	41.5/0.0/-10.1/-59.4
neos-5049753-cuanza	1/1/1	<b>46.2</b>	<b>971.3</b>	418.9	97.0	38.9/-20.7/-22.3/-25.8
neos-5052403-cygnat	3/0/0	<b>0.6</b>	41.6	2.3	0.0	53.8/1.2/0.0/0.0
neos-5093327-huahum	3/0/0	<b>31.2</b>	<b>8.4</b>	<b>87.9</b>	<b>52.8</b>	96.6/37.3/27.2/39.0
neos-5104907-jarama	0/0/2	114.0	1656.1	780.6	315.4	-/-/-/-
neos-5107597-kakapo	3/0/0	35976.9	1.8	129.8	95.8	8.5/0.0/-5.0/-0.9
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	3986.5	<b>4.6</b>	24.9	0.0	0.7/19.3/6.7/0.0
neos-5195221-niemur	3/0/0	737.3	7.1	<b>15.1</b>	0.0	4.0/4.1/19.3/0.0
neos-631710	3/0/0	149.4	2.3	1.0	0.0	0.0/8.0/0.0/0.0
neos-662469	0/3/0	<b>304.9</b>	6.8	20.6	<b>1.3</b>	-26.8/-5.9/-6.3/-46.2
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	2.75e05	105.5	72.3	20.3	7.1/-2.1/-4.1/1.9

(continued)

Table A.17 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-860300	3/0/0	59.0	<i>0.6</i>	<i>6.0</i>	0.0	-3.4/-33.3/-33.3/0.0
neos-873061	3/0/0	57.9	28.3	32.0	<i>2.0</i>	5.4/-9.2/-0.9/-20.0
neos-911970	3/0/0	<i>218.4</i>	0.2	51.7	<i>1.9</i>	-39.6/0.0/-3.3/68.3
neos-933966	3/0/0	<i>197.6</i>	<i>1.4</i>	<i>11.0</i>	0.0	11.8/12.5/-14.5/0.0
neos-950242	3/0/0	<i>70.5</i>	<i>10.1</i>	<i>30.1</i>	<i>0.7</i>	45.1/-33.7/-27.6/-42.9
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	1/1/1	<i>9.2</i>	<i>72.6</i>	275.7	19.1	-75.0/-72.2/-77.5/-89.0
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<i>0.9</i>	8.6	996.5	30.6	35.7/7.5/14.7/-91.5
neos17	3/0/0	316.4	0.2	32.3	1.6	-8.3/0.0/-1.9/0.0
neos20	0/0/3	<i>65.3</i>	10.4	1162.0	100.1	-30.0/-5.8/1.7/-18.7
neos5	3/0/0	<i>68.1</i>	0.1	<i>3.3</i>	0.0	-38.9/0.0/13.2/0.0
neos7	0/3/0	<i>7.7</i>	<i>0.4</i>	<i>39.4</i>	<i>3.2</i>	30.0/-50.0/-36.5/-100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<i>10.6</i>	<i>5.2</i>	<i>36.8</i>	<i>1.1</i>	72.3/-17.3/-30.2/-100.0
netdiversion	3/0/0	90.0	<i>66.8</i>	9.5	0.0	-4.0/10.8/1.0/0.0
nexp-150-20-8-5	3/0/0	145.9	0.5	7.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	<i>12.1</i>	12.7	791.5	191.4	-15.7/6.6/27.5/26.1
nh97t	0/0/3	10.3	<i>23.0</i>	1348.9	463.6	2.8/-44.3/-19.1/-29.6
noswot	0/3/0	10.2	0.1	<i>38.9</i>	<i>2.4</i>	-5.9/0.0/-11.8/-45.8
ns1116954	0/0/3	0.0	<i>713.1</i>	871.9	2.3	0.0/-33.8/-46.4/28.1
ns1208400	1/2/0	0.0	<i>21.6</i>	<i>151.9</i>	<i>8.7</i>	0.0/76.0/61.6/-96.6
ns1644855	3/0/0	<i>0.4</i>	<i>344.4</i>	36.0	<i>2.6</i>	20.0/11.8/-4.2/-34.6
ns1760995	3/0/0	<i>11.0</i>	77.0	75.3	3.2	26.2/9.0/6.5/-9.4
ns1830653	0/0/3	<i>525.3</i>	<i>29.8</i>	860.2	69.3	-68.7/-85.2/-93.2/-98.6
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-idx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	<i>3.7</i>	0.3	19.3	0.0	-10.8/0.0/-1.6/0.0
nursesched-medium-hint03	0/3/0	<i>884.5</i>	<i>21.0</i>	<i>26.4</i>	0.0	-11.1/-33.8/-56.8/0.0
nursesched-sprint02	0/3/0	55.2	<i>2.7</i>	<i>15.6</i>	0.0	0.0/-29.6/-40.4/0.0
nw04	3/0/0	3.9	2.0	8.3	0.0	0.0/0.0/-3.6/0.0
opm2-z10-s4	3/0/0	94.2	27.3	1.0	0.0	0.0/0.0/0.0/0.0
opt1217	3/0/0	<i>0.0</i>	<i>0.2</i>	<i>47.0</i>	<i>6.6</i>	100.0/-50.0/-22.8/-65.2
p200x1188c	3/0/0	<i>4.4</i>	0.2	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/1	0.0	486.3	1263.0	19.0	-/-/-/-
pg	3/0/0	<i>2.4</i>	0.3	52.3	<i>15.9</i>	84.5/0.0/-1.1/17.2
pg5-34	3/0/0	<i>1.5</i>	0.4	53.0	<i>11.7</i>	78.9/0.0/-1.9/14.0
physiciansched3-3	3/0/0	<i>20.9</i>	57.7	<i>77.9</i>	<i>5.2</i>	-58.4/-5.5/-40.9/-80.8
physiciansched6-2	0/0/3	<i>4.0</i>	<i>74.7</i>	922.6	75.9	18.4/11.5/-19.8/-54.2
piperout-08	0/0/3	<i>227.5</i>	<i>44.9</i>	1077.7	32.0	42.4/35.1/37.0/3.9
piperout-27	0/0/3	<i>35.6</i>	<i>43.3</i>	816.9	34.7	84.4/34.4/31.7/-49.3
pk1	3/0/0	<i>257.0</i>	0.2	<i>64.5</i>	<i>6.8</i>	78.4/0.0/-10.1/23.6
pp08a	3/0/0	<i>103.0</i>	0.1	<i>20.4</i>	0.0	-43.3/0.0/-23.5/0.0
pp08aCUTS	3/0/0	<i>41.9</i>	0.1	<i>18.7</i>	0.0	-16.2/0.0/-35.8/0.0
proteindesign121hz512p9	0/3/0	2.4	4.8	22.5	<i>0.0</i>	0.0/4.0/7.8/100.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	1/2/0	<i>52.5</i>	<i>14.8</i>	<i>120.3</i>	<i>7.0</i>	20.5/-43.2/-68.6/-100.0
qap10	3/0/0	19.4	13.7	2.0	0.0	0.0/0.0/0.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	256.9	0.5	25.0	<i>0.3</i>	-6.5/0.0/1.2/-100.0
rB10-011001	3/0/0	209.7	<i>0.6</i>	25.3	<i>0.3</i>	-2.7/-16.7/3.8/-100.0
rB11-010000	3/0/0	<i>228.7</i>	<i>2.1</i>	<i>47.7</i>	<i>1.0</i>	20.8/-38.1/-37.1/-40.0
rB11-110001	3/0/0	<i>137.5</i>	<i>4.1</i>	<i>41.3</i>	<i>1.0</i>	33.7/-36.6/-43.6/-70.0
rB12-111111	1/2/0	<i>74.7</i>	<i>22.3</i>	317.3	22.1	16.9/51.9/44.8/-85.5
rC10-001000	3/0/0	<i>150.3</i>	<i>0.3</i>	30.1	0.0	45.4/-33.3/-7.3/0.0
rC10-100001	2/1/0	<i>561.6</i>	<i>5.9</i>	<i>122.0</i>	<i>1.0</i>	-27.3/-16.9/-16.8/-20.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<i>213.9</i>	<i>10.0</i>	<i>72.5</i>	<i>1.3</i>	33.5/-49.0/-49.8/-38.5
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.17 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
radiationm18-12-05	0/3/0	<b>207.8</b>	<b>4.2</b>	<b>140.5</b>	<b>17.4</b>	-26.8/-57.1/-51.4/-79.3
radiationm40-10-02	0/3/0	<b>4062.1</b>	<b>35.5</b>	<b>332.5</b>	<b>32.9</b>	-89.4/-54.4/-56.8/-72.6
rail01	3/0/0	<b>36.9</b>	1221.0	<b>22.4</b>	0.0	-16.0/4.6/-46.9/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<b>22.2</b>	0.3	<b>20.4</b>	<b>0.0</b>	-25.2/0.0/10.5/100.0
rd-rplusc-21	0/0/3	58.3	<b>30.8</b>	779.3	311.6	-0.3/14.9/10.1/13.6
reblock115	2/1/0	<b>7.4</b>	<b>3.5</b>	<b>129.6</b>	<b>19.0</b>	33.9/-54.3/-57.3/-67.4
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.0	2.0	0.0	0.0/0.7/0.0/0.0
rocl-4-11	0/0/3	<b>77.3</b>	<b>24.0</b>	1039.6	228.7	-10.5/-11.7/-10.3/-54.6
rocll-5-11	1/0/2	91.4	<b>29.2</b>	535.2	144.4	-1.1/-71.2/-70.8/-63.6
roi2alpha3n4	3/0/0	<b>38.5</b>	32.9	34.3	<b>0.8</b>	38.3/1.2/0.0/50.0
roi5alpha10n8	3/0/0	56.0	484.4	<b>33.0</b>	<b>1.3</b>	6.8/-7.8/-12.1/-100.0
roll3000	0/3/0	<b>30.8</b>	1.1	<b>56.3</b>	<b>6.5</b>	-14.9/0.0/-14.0/-30.8
rout	0/3/0	47.0	0.2	39.0	<b>2.9</b>	5.1/0.0/-9.7/-41.4
s100	3/0/0	<b>2.8</b>	<b>243.4</b>	<b>4.0</b>	0.0	-39.3/19.6/39.4/0.0
s250r10	3/0/0	0.1	53.1	2.0	0.0	0.0/0.6/0.0/0.0
satellites2-40	0/3/0	<b>321.1</b>	<b>66.2</b>	<b>147.0</b>	<b>57.0</b>	-23.6/-33.2/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>93.6</b>	409.4	182.4	-60.0/-75.9/-91.5/-98.5
savsched1	0/3/0	8.7	198.0	13.0	0.0	-9.2/-4.0/-5.4/0.0
sct2	3/0/0	29.0	<b>0.7</b>	28.4	<b>0.3</b>	0.7/-14.3/-8.1/50.0
set1ch	3/0/0	<b>51.7</b>	0.1	31.0	1.0	39.6/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<b>8.6</b>	3.0	<b>8.6</b>	0.0	-83.7/-10.0/-11.6/0.0
sing326	3/0/0	<b>24.6</b>	<b>31.5</b>	<b>43.3</b>	<b>5.2</b>	-56.9/-21.6/-21.5/-69.2
sing44	3/0/0	<b>10.4</b>	<b>29.7</b>	<b>44.5</b>	<b>6.6</b>	-28.8/-11.1/-13.5/-42.4
snp-02-004-104	0/3/0	<b>2.2</b>	20.1	34.0	1.9	-22.7/-2.0/-1.2/0.0
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.7	<b>1.6</b>	0.0/0.0/-1.3/-18.8
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.2	<b>54.4</b>	<b>8.0</b>	0.0	-0.6/12.4/38.5/0.0
square41	0/2/0	9.5	1872.9	15.7	0.0	-/-/-/-
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>142.4</b>	113.2	13.5	0.0	16.4/-2.7/0.7/0.0
supportcase12	0/3/0	1.8	15.3	<b>25.4</b>	0.0	0.0/-4.6/-17.3/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>2413.1</b>	0.2	90.0	59.7	74.3/0.0/-0.3/5.7
supportcase33	0/2/1	<b>77.1</b>	<b>27.8</b>	304.8	24.4	-16.3/-50.4/-60.2/-40.6
supportcase40	3/0/0	<b>14.6</b>	4.1	17.7	0.0	17.0/2.4/-6.2/0.0
supportcase42	0/3/0	<b>17.1</b>	<b>6.5</b>	<b>17.2</b>	0.0	29.9/-35.4/-32.6/0.0
supportcase6	3/0/0	<b>0.5</b>	<b>16.9</b>	<b>17.2</b>	0.0	-20.0/-21.3/-30.2/0.0
supportcase7	3/0/0	<b>10.5</b>	8.8	26.0	0.0	26.6/-5.7/0.0/0.0
swath	0/1/2	<b>141.9</b>	<b>68.8</b>	698.0	289.3	21.9/-80.4/-73.1/-79.4
swath1	3/0/0	<b>12.7</b>	<b>2.0</b>	61.6	14.4	79.0/13.0/1.0/8.3
swath3	3/0/0	<b>40.8</b>	<b>2.4</b>	<b>72.3</b>	<b>19.4</b>	-18.6/-37.5/-40.7/-83.5
t1717	3/0/0	<b>71.2</b>	<b>180.8</b>	<b>76.8</b>	<b>0.6</b>	60.3/-30.1/-43.4/-100.0
tbfp-network	3/0/0	<b>36.7</b>	<b>15.4</b>	15.3	0.0	81.6/31.2/-8.5/0.0
thor50dday	3/0/0	257.8	7.3	24.5	1.7	0.0/-1.4/0.0/0.0
timtab1	0/3/0	59.4	<b>0.5</b>	<b>89.4</b>	<b>24.9</b>	-6.6/16.7/21.4/10.8
timtab2	0/2/1	<b>87.6</b>	<b>4.6</b>	498.6	224.7	-16.0/20.7/37.0/16.9
tr12-30	3/0/0	<b>48.4</b>	0.2	<b>36.0</b>	<b>3.6</b>	33.6/0.0/-11.9/-55.6
traininstance2	0/0/3	<b>440.2</b>	<b>4.9</b>	858.8	227.8	-44.7/-32.7/-24.4/-69.9
traininstance6	0/3/0	<b>212.8</b>	<b>0.3</b>	102.6	23.7	53.9/75.0/66.5/43.7
trento1	3/0/0	<b>223.4</b>	8.5	9.3	0.0	-16.2/-5.9/0.0/0.0
triptim1	0/3/0	0.1	22.4	4.2	0.0	0.0/3.9/-4.8/0.0
uccase12	3/0/0	1.9	10.7	16.6	0.0	0.0/-3.7/-6.0/0.0
uccase9	3/0/0	<b>4472.1</b>	<b>33.2</b>	98.6	38.3	20.3/42.7/48.0/47.5
uct-subprob	3/0/0	<b>14.6</b>	<b>0.5</b>	<b>9.6</b>	0.0	-15.1/16.7/-19.8/0.0
unitcal-7	0/0/3	<b>15.3</b>	<b>102.8</b>	726.7	39.4	42.9/25.3/26.7/73.0

(continued)

Table A.17 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
var-smallemerly-m6j6	3/0/0	<b>23.1</b>	26.4	<b>76.0</b>	<b>12.6</b>	91.0/-9.1/-11.2/-19.8
vpm2	3/0/0	45.0	0.1	<b>30.3</b>	<b>0.6</b>	0.0/0.0/-32.7/-100.0
wachplan	0/3/0	0.0	<b>3.4</b>	<b>38.3</b>	<b>0.3</b>	0.0/-11.8/-30.8/-100.0
Geom. means			(269 instances)	(225 instances)		
FP		45.8	5.2	15.5	1.1	
FP+(3,sd,h)		<b>40.7</b>	<b>5.7</b>	<b>17.5</b>	<b>1.5</b>	

Table A.18.: Performance of FP+(3,sv,h)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	3/0/0	<b>1.1</b>	<b>0.6</b>	<b>9.5</b>	<b>0.0</b>	90.9/95.1/94.0/100.0
30n20b8	0/2/1	<b>677.3</b>	<b>11.4</b>	367.7	69.3	-31.8/-50.0/-54.6/-58.3
50v-10	0/3/0	132.0	0.3	<b>20.4</b>	<b>0.0</b>	-5.5/0.0/11.3/100.0
CMS750-4	3/0/0	58.1	<b>6.7</b>	<b>98.6</b>	<b>14.5</b>	-8.8/-38.8/-34.0/-17.2
a1c1s1	3/0/0	<b>30.1</b>	<b>0.5</b>	31.7	<b>1.6</b>	43.0/-20.0/-1.3/-18.8
academic timetable small	0/0/2	inf	545.0	1146.2	40.0	-/-/-/-
aflow30a	3/0/0	<b>94.6</b>	<b>0.2</b>	36.3	<b>3.5</b>	28.1/-50.0/-7.7/-42.9
aflow40b	3/0/0	196.6	<b>0.5</b>	<b>36.6</b>	<b>3.8</b>	5.2/-40.0/-12.6/-60.5
air04	3/0/0	<b>0.7</b>	<b>3.7</b>	<b>16.9</b>	0.0	-85.7/-29.7/-60.9/0.0
air05	3/0/0	<b>3.1</b>	<b>1.8</b>	<b>16.7</b>	0.0	24.4/-55.6/-76.0/0.0
app1-1	3/0/0	<b>42.0</b>	<b>1.0</b>	<b>53.5</b>	<b>16.3</b>	-92.6/-50.0/-35.3/-75.5
app1-2	3/0/0	43.9	<b>18.7</b>	<b>79.7</b>	<b>27.8</b>	0.0/-42.8/-35.0/-45.0
arki001	0/2/1	3.0	<b>14.5</b>	645.2	176.8	-3.3/30.0/19.8/5.2
assign1-5-8	3/0/0	<b>1.0</b>	0.1	22.2	0.0	47.4/0.0/0.4/0.0
atlanta-ip	3/0/0	<b>12.2</b>	18.7	<b>35.7</b>	<b>0.8</b>	32.2/-9.6/-27.7/-25.0
b1c1s1	3/0/0	<b>126.8</b>	0.5	36.3	<b>4.9</b>	21.4/0.0/-7.2/-26.5
bab2	1/0/2	<b>8.3</b>	<b>457.8</b>	317.0	40.1	67.5/-31.4/-45.4/-41.4
bab6	0/1/2	23.3	<b>377.3</b>	515.6	55.7	1.7/-72.3/-83.0/-72.5
beasleyC3	3/0/0	11.6	0.2	35.7	<b>5.6</b>	0.0/0.0/-2.0/-14.3
binkar10-1	3/0/0	3.9	0.1	<b>7.7</b>	0.0	2.5/0.0/51.0/0.0
blp-ar98	3/0/0	<b>96.5</b>	<b>3.0</b>	<b>24.4</b>	<b>0.6</b>	-26.1/-33.3/-30.7/-100.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/1	0.0	222.3	1771.0	1.0	-/-/-/-
bppc4-08	3/0/0	<b>37.0</b>	1.2	63.3	9.7	28.3/0.0/-1.6/-4.1
brazil3	0/3/0	<b>440.4</b>	22.6	<b>28.1</b>	0.0	30.6/-6.6/-23.8/0.0
buildingenergy	0/3/0	1.1	<b>782.1</b>	11.0	0.0	0.0/-10.9/6.0/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	3.0	40.7	10.7	0.0/-10.0/-1.7/-6.5
chromaticindex1024-7	3/0/0	0.0	<b>62.9</b>	<b>2.3</b>	0.0	0.0/-12.9/23.3/0.0
chromaticindex512-7	3/0/0	0.0	47.2	2.0	0.0	0.0/-4.7/0.0/0.0
cmflsp50-24-8-8	1/1/1	19.1	<b>55.7</b>	365.5	97.3	2.1/66.7/65.2/67.0
co-100	3/0/0	302.3	6.7	16.3	0.0	0.2/-9.0/-4.3/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	3645.7	5.8	24.5	0.0	-6.0/6.5/-2.0/0.0
comp21-2idx	0/3/0	407.4	4.8	<b>28.9</b>	<b>0.3</b>	4.6/-4.2/-13.1/-100.0
cost266-UUE	3/0/0	37.3	<b>0.5</b>	<b>28.3</b>	0.3	-5.9/-20.0/-17.0/0.0
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/1/2	<b>35.9</b>	<b>7.3</b>	726.9	145.6	48.0/-16.4/-47.4/-66.1
csched008	1/1/1	9.4	<b>3.7</b>	370.9	98.8	4.1/-54.1/-59.0/-75.7
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	18.4	<b>18.0</b>	0.0	0.0/1.6/-10.0/0.0
dano3-5	3/0/0	0.2	<b>135.4</b>	<b>49.9</b>	<b>9.2</b>	0.0/-67.5/-39.7/-90.2
dano3mip	3/0/0	<b>11.9</b>	<b>160.2</b>	72.6	<b>15.0</b>	30.8/42.8/-2.8/18.0
danooint	1/2/0	651.4	3.9	<b>207.6</b>	<b>89.2</b>	0.0/2.5/-46.3/-53.8
disctom	3/0/0	0.0	<b>1.5</b>	2.0	0.0	0.0/-13.3/0.0/0.0
drayage-100-23	3/0/0	<b>7.7</b>	<b>0.5</b>	<b>16.4</b>	0.0	-27.3/-40.0/-20.7/0.0
drayage-25-23	3/0/0	<b>5.5</b>	<b>0.5</b>	15.9	0.0	46.1/-20.0/3.0/0.0

(continued)

Table A.18 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
ds	3/0/0	4945.0	6.2	1.0	0.0	0.0/-3.2/0.0/0.0
dws008-01	0/1/2	<b>30.1</b>	80.5	1134.2	394.2	68.6/-7.3/-27.7/-40.2
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0	0.0/0.0/0.0/0.0
enlight-hard	0/0/3	0.0	4.2	720.3	203.6	-/-/-/-
exp-1-500-5-5	3/0/0	<b>51.1</b>	0.1	27.6	0.0	32.2/0.0/-2.5/0.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>604.6</b>	<b>0.3</b>	19.3	0.0	33.4/25.0/4.9/0.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>12.5</b>	<b>6.1</b>	52.3	<b>3.4</b>	27.3/12.9/6.6/26.1
fiber	3/0/0	142.9	0.1	<b>19.3</b>	0.0	7.0/0.0/-22.8/0.0
fixnet6	3/0/0	39.1	0.1	31.0	1.0	8.2/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>14.7</b>	0.1	<b>6.2</b>	<b>0.7</b>	-28.6/0.0/-53.2/-100.0
germanrr	0/3/0	<b>6.9</b>	<b>19.5</b>	<b>102.9</b>	<b>22.2</b>	-40.6/-40.0/-50.6/-73.4
gesa2	0/3/0	2.4	0.2	20.4	0.0	0.0/0.0/0.0/0.0
gesa2-o	0/3/0	<b>5.5</b>	0.2	34.6	1.6	72.5/0.0/2.8/-6.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	1/2/0	<b>962.1</b>	<b>0.5</b>	<b>161.9</b>	<b>57.0</b>	-29.2/-40.0/-35.6/-43.5
gmu-35-40	3/0/0	6.5	<b>0.2</b>	<b>15.9</b>	0.0	0.0/-50.0/-11.9/0.0
gmu-35-50	3/0/0	<b>6.8</b>	<b>0.4</b>	<b>42.6</b>	<b>2.9</b>	44.3/-25.0/-26.3/-65.5
graph20-20-1rand	3/0/0	<b>16.1</b>	4.2	<b>48.3</b>	<b>2.4</b>	-13.0/-2.4/-35.2/-83.3
graphdraw-domain	0/3/0	<b>114.5</b>	<b>0.4</b>	<b>96.6</b>	<b>25.7</b>	-74.8/-25.0/-37.2/-59.5
h80x6320d	3/0/0	22.6	1.1	32.3	<b>2.3</b>	-2.7/8.3/-0.9/-17.4
harp2	3/0/0	11.3	0.1	12.3	0.0	8.9/0.0/3.1/0.0
highschool1-aigio	0/3/0	inf	<b>1028.2</b>	<b>31.0</b>	0.0	0.0/-33.0/-50.6/0.0
hypothyroid-k1	3/0/0	0.0	<b>5.5</b>	1.0	0.0	0.0/-12.7/0.0/0.0
ic97p	0/2/1	<b>13.1</b>	<b>2.7</b>	318.1	118.7	14.9/47.1/64.1/42.2
ic97t	0/0/3	13.0	4.2	1196.0	410.4	-4.6/-7.1/5.6/-24.2
icir97p	0/0/3	<b>19.1</b>	<b>24.6</b>	1070.7	311.2	16.6/-12.2/6.1/-30.7
icir97t	0/2/1	<b>13.5</b>	<b>12.9</b>	448.6	269.9	14.0/-65.9/-53.1/-52.3
irish-electricity	3/0/0	6.2	<b>22.3</b>	<b>27.7</b>	<b>0.6</b>	-3.2/-13.0/-12.6/-50.0
irp	3/0/0	<b>1.8</b>	0.3	<b>3.0</b>	0.0	52.6/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>30.0</b>	6.3	22.6	0.0	16.7/1.6/-2.7/0.0
k1mushroom	3/0/0	18.2	43.4	1.0	0.0	0.0/-8.3/0.0/0.0
lectsched-5-obj	0/0/3	2361.3	<b>107.0</b>	1048.4	2.8	-4.9/-21.5/-13.3/60.0
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	674.7	<b>1.3</b>	89.7	56.6	0.0/-15.4/0.3/0.0
lotsize	3/0/0	72.5	<b>0.6</b>	<b>51.0</b>	<b>14.0</b>	-2.5/-16.7/-12.0/-25.0
mad	3/0/0	<b>6322.9</b>	0.1	14.7	0.0	48.8/0.0/0.0/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>37.3</b>	50.7	<b>68.6</b>	<b>18.0</b>	16.6/-1.6/-47.8/-82.2
map16715-04	3/0/0	<b>100.0</b>	56.3	<b>62.6</b>	<b>15.3</b>	-10.8/1.1/-26.0/-40.5
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>52.7</b>	0.2	90.0	<b>7.7</b>	88.9/0.0/0.0/47.3
mas76	0/3/0	<b>14.2</b>	0.2	90.0	<b>10.9</b>	86.6/0.0/0.8/49.3
mc11	3/0/0	102.1	0.4	43.0	13.0	5.6/0.0/-0.9/-5.4
mcsched	3/0/0	<b>16.3</b>	0.5	4.0	0.0	-20.9/0.0/-10.0/0.0
mik-250-20-75-4	0/3/0	<b>70.1</b>	<b>0.1</b>	<b>15.1</b>	<b>0.9</b>	-12.8/50.0/60.6/80.0
milo-v12-6-r2-40-1	3/0/0	<b>110.0</b>	1.0	42.3	12.3	26.8/-10.0/-0.7/-2.4
misc07	3/0/0	<b>11.1</b>	<b>0.2</b>	<b>22.9</b>	0.0	61.2/-50.0/-12.2/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>5.0</b>	<b>0.4</b>	<b>23.1</b>	0.0	64.3/-25.0/-15.2/0.0
modglob	3/0/0	<b>143.5</b>	0.1	31.3	1.3	-26.2/0.0/0.0/0.0
momentum1	0/1/2	188.5	<b>61.8</b>	844.8	424.9	2.5/-36.1/-34.0/-16.9
msc98-ip	3/0/0	<b>10.7</b>	6.3	32.9	<b>1.5</b>	31.0/0.0/-6.7/-60.0
mushroom-best	0/3/0	9.58e06	<b>19.5</b>	<b>60.4</b>	<b>1.5</b>	-4.3/-30.3/-33.8/11.8

(continued)



Table A.18 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
mzzv11	0/3/0	19.9	3.9	<b>27.3</b>	<b>0.3</b>	1.0/7.1/-29.3/-100.0
mzzv42z	0/3/0	<b>26.5</b>	<b>3.6</b>	22.0	<b>0.0</b>	14.5/26.5/7.6/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>18.2</b>	<b>0.6</b>	<b>30.3</b>	<b>0.6</b>	-48.4/-50.0/-32.7/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>1.6</b>	5.2	<b>32.6</b>	<b>2.1</b>	-43.8/-5.8/-19.0/-71.4
neos-1171737	3/0/0	4.3	1.5	<b>34.9</b>	<b>3.4</b>	-9.3/6.3/-15.2/-82.4
neos-1354092	0/3/0	<b>2.1</b>	<b>136.7</b>	39.3	<b>0.8</b>	88.4/22.5/-4.3/-100.0
neos-1445765	3/0/0	32.3	<b>0.7</b>	<b>6.3</b>	0.0	8.8/12.5/-11.1/0.0
neos-1456979	0/2/1	<b>75.5</b>	<b>31.6</b>	405.6	117.0	49.6/21.8/12.3/-17.5
neos-1582420	0/2/1	<b>91.5</b>	<b>12.5</b>	673.2	112.8	-24.6/-88.0/-88.2/-91.7
neos-2657525-crna	0/3/0	974.4	<b>0.6</b>	<b>66.5</b>	<b>7.6</b>	4.1/-66.7/-37.1/-73.7
neos-2746589-doon	0/0/3	<b>6.9</b>	<b>277.9</b>	728.6	35.2	80.2/-50.3/-65.9/-11.1
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	1/2/0	<b>2.6</b>	<b>13.1</b>	<b>76.0</b>	<b>22.1</b>	-88.5/-27.5/-28.6/-33.0
neos-3004026-krka	0/0/3	0.0	<b>80.8</b>	970.8	3.3	0.0/25.9/24.5/8.3
neos-3024952-loue	0/0/3	876.2	<b>214.0</b>	1862.5	1.2	-7.2/-62.7/-24.1/95.7
neos-3046615-murg	0/3/0	10298.4	0.2	99.7	67.9	5.5/0.0/-5.4/-3.4
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/1/2	125.7	<b>176.7</b>	782.7	96.4	-3.8/61.5/28.6/-100.0
neos-3381206-awhea	0/0/3	4.9	19.3	737.2	0.0	0.0/-5.2/30.1/100.0
neos-3402294-bobin	3/0/0	<b>519.0</b>	<b>24.4</b>	<b>27.7</b>	<b>0.7</b>	-17.3/-17.6/-31.0/-100.0
neos-355904-turama	2/1/0	<b>4.3</b>	<b>95.1</b>	<b>47.0</b>	<b>0.6</b>	-53.5/-17.8/-33.2/-33.3
neos-3627168-kasai	3/0/0	1.5	0.1	20.4	0.0	0.0/0.0/0.0/0.0
neos-3656078-kumeu	0/0/3	<b>24.3</b>	141.1	1200.6	0.0	21.1/-0.6/-13.3/100.0
neos-3754480-nidda	3/0/0	<b>9.5</b>	0.2	67.3	<b>10.3</b>	97.4/0.0/0.6/24.3
neos-4300652-rahue	0/1/2	<b>182.2</b>	387.6	379.5	0.8	31.5/6.1/-6.5/-62.5
neos-4338804-snowy	0/3/0	<b>51216.8</b>	<b>1.0</b>	<b>121.3</b>	<b>31.2</b>	55.1/-20.0/-17.1/-10.3
neos-4387871-tavua	0/1/2	<b>951.7</b>	<b>29.7</b>	1115.9	581.1	-20.7/-22.9/-28.1/-26.4
neos-4413714-turia	3/0/0	<b>2.8</b>	80.8	<b>71.4</b>	<b>10.9</b>	93.6/-1.1/10.4/16.2
neos-4532248-waihi	1/1/1	949.4	484.5	392.9	84.5	0.0/0.9/10.6/-57.3
neos-4647030-tutaki	3/0/0	<b>5.4</b>	<b>28.9</b>	<b>32.3</b>	<b>1.6</b>	75.5/-39.4/-45.2/-100.0
neos-4722843-widden	0/3/0	<b>60.9</b>	<b>66.1</b>	97.8	28.2	69.2/-16.6/-5.5/-9.2
neos-4738912-atrato	0/3/0	<b>6.9</b>	<b>0.5</b>	<b>21.5</b>	0.0	42.5/-40.0/-42.3/0.0
neos-4763324-toguru	3/0/0	54.3	<b>24.1</b>	25.4	0.0	8.3/-12.4/-6.7/0.0
neos-4954672-berkel	3/0/0	<b>30.8</b>	0.1	34.3	<b>2.1</b>	43.7/0.0/-6.7/-38.1
neos-5049753-cuanza	0/1/2	<b>45.5</b>	<b>1193.2</b>	472.4	109.2	39.8/-35.4/-31.1/-34.1
neos-5052403-cygnnet	3/0/0	<b>0.6</b>	44.7	2.3	0.0	53.8/-5.8/0.0/0.0
neos-5093327-huahum	3/0/0	<b>32.3</b>	<b>8.6</b>	<b>87.6</b>	<b>52.5</b>	96.5/35.8/27.4/39.4
neos-5104907-jarama	0/1/1	42.1	1370.6	469.7	106.9	-/-/-/-
neos-5107597-kakapo	3/0/0	<b>34021.0</b>	2.0	132.5	99.6	13.4/-10.0/-6.9/-4.7
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	<b>4656.3</b>	<b>4.4</b>	26.3	0.0	-13.8/22.8/1.5/0.0
neos-5195221-niemur	3/0/0	<b>655.5</b>	<b>4.3</b>	<b>11.9</b>	0.0	14.6/41.9/36.4/0.0
neos-631710	3/0/0	149.4	2.5	1.0	0.0	0.0/0.0/0.0/0.0
neos-662469	0/3/0	<b>330.1</b>	<b>5.7</b>	<b>14.4</b>	<b>0.0</b>	-32.4/10.9/25.4/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	<b>0.6</b>	0.0	0.0	0.0/-16.7/0.0/0.0
neos-848589	3/0/0	<b>272.6</b>	<b>80.8</b>	<b>53.8</b>	<b>12.2</b>	99.9/21.8/22.4/41.1
neos-860300	3/0/0	57.7	<b>0.5</b>	<b>5.3</b>	0.0	-1.2/-20.0/-24.5/0.0
neos-873061	3/0/0	58.7	26.1	31.7	1.6	4.1/-1.5/0.0/0.0
neos-911970	3/0/0	127.4	0.2	53.6	<b>5.0</b>	3.5/0.0/-6.7/16.7
neos-933966	3/0/0	<b>157.7</b>	<b>1.4</b>	10.3	0.0	29.6/12.5/-8.7/0.0
neos-950242	2/1/0	<b>22.4</b>	<b>15.5</b>	<b>45.7</b>	<b>2.4</b>	82.5/-56.8/-52.3/-83.3
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	0/1/2	<b>1.8</b>	<b>105.7</b>	452.6	24.3	21.7/-80.9/-86.3/-91.4
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<b>0.4</b>	8.5	980.3	34.4	71.4/8.6/16.1/-92.4
neos17	3/0/0	295.4	0.2	32.3	1.6	-1.8/0.0/-1.9/0.0
neos20	0/1/2	<b>76.6</b>	<b>15.1</b>	1615.5	122.3	-40.3/-35.1/-26.9/-33.4

(continued)

Table A.18 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos5	3/0/0	<b>70.0</b>	0.1	<b>3.3</b>	0.0	-40.6/0.0/13.2/0.0
neos7	0/3/0	<b>4.9</b>	<b>0.3</b>	<b>27.9</b>	0.0	55.5/-33.3/-10.4/0.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>24.2</b>	<b>3.1</b>	<b>20.5</b>	0.0	36.8/27.9/20.2/0.0
netdiversion	3/0/0	84.5	69.1	8.7	0.0	2.2/7.7/9.4/0.0
nexp-150-20-8-5	3/0/0	145.9	<b>0.6</b>	7.0	0.0	0.0/-16.7/0.0/0.0
nh97p	0/0/3	10.4	14.4	682.4	150.5	-1.9/-5.6/37.5/41.9
nh97t	0/0/3	10.1	<b>25.5</b>	1136.6	309.4	4.7/-49.8/-4.0/5.3
noswot	0/3/0	9.5	0.1	<b>28.5</b>	<b>0.3</b>	1.0/0.0/16.9/76.9
ns1116954	0/0/3	0.0	<b>1329.7</b>	1548.8	5.4	0.0/-64.5/-69.8/-40.7
ns1208400	2/1/0	0.0	<b>15.9</b>	<b>109.2</b>	<b>1.4</b>	0.0/82.4/72.4/-78.6
ns1644855	3/0/0	<b>0.4</b>	386.4	36.0	<b>2.6</b>	20.0/1.1/-4.2/-34.6
ns1760995	3/0/0	<b>11.5</b>	79.3	75.3	<b>4.2</b>	22.8/6.3/6.5/-31.0
ns1830653	1/0/2	<b>520.9</b>	<b>17.0</b>	448.1	43.0	-68.5/-74.1/-86.9/-97.7
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ipx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.5	<b>0.4</b>	18.6	0.0	-5.7/-25.0/2.1/0.0
nursesched-medium-hint03	0/3/0	785.7	<b>18.1</b>	<b>22.6</b>	0.0	0.1/-23.2/-49.6/0.0
nursesched-sprint02	0/3/0	55.2	<b>2.8</b>	<b>17.6</b>	0.0	0.0/-32.1/-47.2/0.0
nw04	3/0/0	3.9	2.0	<b>9.3</b>	0.0	0.0/0.0/-14.0/0.0
opm2-z10-s4	3/0/0	94.2	26.9	1.0	0.0	0.0/1.5/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	<b>0.2</b>	<b>47.7</b>	<b>7.2</b>	100.0/-50.0/-23.9/-68.1
p200x1188c	3/0/0	<b>4.4</b>	0.2	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	82.1	0.1	5.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/2	0.0	710.6	1236.0	7.8	-/-/-/-
pg	3/0/0	<b>2.3</b>	0.3	52.3	<b>15.8</b>	85.2/0.0/-1.1/17.7
pg5-34	3/0/0	<b>1.5</b>	0.4	52.0	<b>10.3</b>	78.9/0.0/0.0/24.3
physiciansched3-3	2/0/1	<b>30.5</b>	<b>78.8</b>	116.0	4.5	-71.5/-30.8/-60.3/-77.8
physiciansched6-2	0/0/3	<b>3.2</b>	<b>72.8</b>	838.7	23.4	34.7/13.7/-11.7/32.8
piperout-08	0/0/3	<b>86.2</b>	<b>43.7</b>	905.4	34.3	78.2/36.8/47.1/-2.9
piperout-27	0/0/3	<b>60.4</b>	<b>57.6</b>	1087.8	35.5	73.6/12.7/9.1/-50.4
pk1	3/0/0	<b>459.4</b>	0.2	<b>66.8</b>	<b>8.0</b>	61.5/0.0/-13.2/10.1
pp08a	3/0/0	<b>31.9</b>	0.1	<b>19.9</b>	0.0	45.4/0.0/-21.6/0.0
pp08aCUTS	3/0/0	<b>8.8</b>	0.1	<b>20.4</b>	0.0	74.9/0.0/-41.2/0.0
proteindesign121hz512p9	0/3/0	2.4	5.2	22.5	<b>0.0</b>	0.0/-3.8/7.8/100.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	3/0/0	<b>51.7</b>	<b>3.5</b>	<b>18.0</b>	0.0	21.7/58.3/52.4/0.0
qap10	3/0/0	19.4	14.4	2.0	0.0	0.0/-4.9/0.0/0.0
qiu	3/0/0	1563.9	0.1	<b>3.8</b>	0.0	0.0/0.0/-13.2/0.0
rB10-011000	3/0/0	257.8	<b>0.7</b>	25.6	0.0	-6.8/-28.6/-1.2/0.0
rB10-011001	3/0/0	198.1	<b>0.6</b>	27.0	0.0	2.9/-16.7/-2.6/0.0
rB11-010000	3/0/0	317.9	<b>1.7</b>	33.2	<b>0.8</b>	-9.2/-23.5/-9.6/-25.0
rB11-110001	3/0/0	211.9	2.6	25.3	<b>0.0</b>	-2.1/0.0/-7.9/100.0
rB12-111111	1/2/0	<b>70.6</b>	<b>35.5</b>	518.1	29.6	21.5/23.5/9.9/-89.2
rC10-001000	3/0/0	<b>168.0</b>	<b>0.3</b>	<b>34.3</b>	<b>1.3</b>	38.9/-33.3/-18.7/-100.0
rC10-100001	2/1/0	446.9	<b>6.2</b>	<b>127.2</b>	<b>0.6</b>	-8.6/-21.0/-20.2/25.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>359.9</b>	5.5	37.8	<b>1.1</b>	-10.6/-7.3/-3.7/-27.3
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>122.7</b>	<b>4.6</b>	<b>128.1</b>	<b>12.2</b>	19.3/-60.9/-46.7/-70.5
radiationm40-10-02	0/3/0	<b>4080.3</b>	<b>37.9</b>	<b>335.6</b>	<b>32.6</b>	-89.4/-57.3/-57.2/-72.4
rail01	3/0/0	<b>37.1</b>	1202.6	<b>16.0</b>	0.0	-16.4/6.1/-25.6/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<b>52.1</b>	<b>0.4</b>	23.3	<b>0.6</b>	-68.1/-25.0/-2.1/-50.0
rd-rplusc-21	0/0/3	57.2	<b>50.9</b>	1224.2	513.3	1.5/-28.9/-29.2/-29.7
reblock115	3/0/0	<b>8.8</b>	<b>2.6</b>	<b>96.7</b>	<b>16.0</b>	21.4/-38.5/-42.7/-61.3
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	14.2	2.0	0.0	0.0/-0.7/0.0/0.0
rocl-4-11	0/0/3	<b>88.3</b>	23.0	1147.0	292.1	-21.6/-7.8/-18.7/-64.5

(continued)

Table A.18 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
rocll-5-11	0/0/3	85.6	49.0	907.4	362.9	5.3/-82.9/-82.8/-85.5
roi2alpha3n4	3/0/0	<b>36.1</b>	<b>38.2</b>	37.2	<b>2.6</b>	42.1/-12.8/-7.8/-38.5
roi5alpha10n8	3/0/0	54.6	493.0	30.9	<b>0.4</b>	9.2/-9.4/-6.1/-100.0
roll3000	0/3/0	26.0	<b>1.5</b>	<b>80.6</b>	<b>14.3</b>	0.8/-26.7/-40.0/-68.5
rout	0/3/0	<b>34.4</b>	<b>0.1</b>	38.4	<b>2.3</b>	30.5/50.0/-8.3/-26.1
s100	3/0/0	<b>2.8</b>	<b>271.0</b>	<b>4.0</b>	0.0	-39.3/10.5/39.4/0.0
s250r10	3/0/0	0.1	<b>59.6</b>	2.0	0.0	0.0/-10.4/0.0/0.0
satellites2-40	0/3/0	<b>312.0</b>	<b>66.8</b>	<b>147.0</b>	<b>57.0</b>	-21.3/-33.8/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>223.5</b>	<b>95.5</b>	409.6	182.5	-60.0/-76.3/-91.5/-98.5
savsched1	0/3/0	<b>9.6</b>	199.1	13.0	0.0	-17.7/-4.5/-5.4/0.0
sct2	3/0/0	<b>43.7</b>	<b>0.8</b>	<b>33.5</b>	<b>1.1</b>	-33.2/-25.0/-22.1/-45.5
set1ch	3/0/0	<b>95.3</b>	0.1	31.0	1.0	-10.2/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<b>1.1</b>	2.9	<b>8.6</b>	0.0	21.4/-6.9/-11.6/0.0
sing326	3/0/0	<b>39.9</b>	<b>31.9</b>	<b>45.9</b>	<b>4.6</b>	-73.4/-22.6/-25.9/-65.2
sing44	3/0/0	<b>10.9</b>	<b>31.6</b>	<b>45.9</b>	<b>7.3</b>	-32.1/-16.5/-16.1/-47.9
snp-02-004-104	0/3/0	1.7	<b>23.4</b>	33.6	1.9	0.0/-15.8/0.0/0.0
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.7	<b>1.6</b>	0.0/0.0/-1.3/-18.8
sp97ar	3/0/0	28.5	0.9	2.2	0.0	-6.7/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	98.2	68.8	<b>15.0</b>	0.0	0.4/-9.7/-13.3/0.0
square41	0/2/0	11.7	2167.1	16.9	0.0	-/-/-/-
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	184.7	122.1	13.0	0.0	-7.8/-9.8/4.4/0.0
supportcase12	0/3/0	1.9	13.6	21.2	0.0	-5.3/6.8/-0.9/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>2413.1</b>	0.2	90.0	59.7	74.3/0.0/-0.3/5.7
supportcase33	0/3/0	61.3	<b>40.8</b>	<b>442.0</b>	<b>85.7</b>	5.0/-66.2/-72.6/-83.1
supportcase40	3/0/0	<b>14.6</b>	4.1	18.0	0.0	17.0/2.4/-7.8/0.0
supportcase42	0/3/0	<b>14.3</b>	<b>5.2</b>	<b>14.1</b>	0.0	41.4/-19.2/-17.7/0.0
supportcase6	3/0/0	<b>0.5</b>	<b>17.4</b>	<b>15.6</b>	0.0	-20.0/-23.6/-23.1/0.0
supportcase7	3/0/0	<b>10.5</b>	8.7	26.0	0.0	26.6/-4.6/0.0/0.0
swath	0/1/2	183.0	<b>61.5</b>	593.1	229.0	-0.8/-78.0/-68.3/-74.0
swath1	3/0/0	<b>12.2</b>	<b>2.0</b>	62.9	15.0	79.8/13.0/-1.1/4.5
swath3	3/0/0	<b>21.6</b>	1.6	46.6	<b>6.6</b>	34.9/-6.3/-7.9/-51.5
t1717	2/1/0	<b>139.3</b>	<b>157.5</b>	<b>81.2</b>	<b>0.4</b>	22.3/-19.8/-46.4/-100.0
tbfp-network	3/0/0	<b>36.7</b>	<b>16.7</b>	15.3	0.0	81.6/25.4/-8.5/0.0
thor50dday	3/0/0	257.8	<b>8.1</b>	24.5	1.7	0.0/-11.1/0.0/0.0
timtab1	0/3/0	57.1	<b>0.4</b>	<b>70.6</b>	<b>17.2</b>	-2.8/33.3/37.9/38.4
timtab2	0/2/1	68.9	<b>4.0</b>	367.0	137.7	6.4/31.0/53.6/49.1
tr12-30	3/0/0	<b>44.3</b>	0.2	<b>36.0</b>	<b>3.6</b>	39.2/0.0/-11.9/-55.6
traininstance2	0/1/2	<b>335.7</b>	<b>5.5</b>	862.7	226.2	-27.4/-40.0/-24.7/-69.7
traininstance6	0/3/0	<b>1018.5</b>	<b>0.9</b>	195.1	41.8	-54.7/25.0/36.2/0.7
trento1	3/0/0	<b>223.4</b>	8.8	10.0	0.0	-16.2/-9.1/-7.0/0.0
triptim1	0/3/0	0.1	23.3	4.2	0.0	0.0/0.0/-4.8/0.0
uccase12	3/0/0	<b>1.3</b>	10.2	16.6	0.0	31.6/1.0/-6.0/0.0
uccase9	3/0/0	<b>4478.2</b>	<b>31.8</b>	98.6	39.2	20.2/45.1/48.0/46.3
uct-subprob	3/0/0	<b>15.9</b>	<b>0.5</b>	<b>10.6</b>	0.0	-22.0/16.7/-27.4/0.0
unitcal-7	0/0/3	<b>34.3</b>	<b>122.9</b>	868.4	130.3	-21.9/10.7/12.4/10.7
var-smallemergy-m6j6	3/0/0	<b>19.4</b>	<b>26.8</b>	<b>75.6</b>	<b>14.0</b>	92.4/-10.4/-10.7/-27.9
vpm2	3/0/0	41.7	0.1	<b>28.6</b>	<b>0.3</b>	7.3/0.0/-28.7/-100.0
wachplan	0/3/0	0.0	<b>3.5</b>	<b>36.4</b>	<b>0.3</b>	0.0/-14.3/-27.2/-100.0
Geom. means			(270 instances)	(222 instances)		
FP		46.0	5.3	15.1	1.0	
FP+(3,sv,h)		<b>38.0</b>	<b>5.8</b>	<b>16.6</b>	<b>1.3</b>	

Table A.19.: Performance of FP+(c)

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	3/0/0	<b>9.3</b>	<b>3.4</b>	<b>46.5</b>	<b>0.3</b>	23.1/72.1/70.9/75.0
30n20b8	0/3/0	<b>348.3</b>	6.1	<b>202.8</b>	<b>44.3</b>	24.6/-6.6/-17.7/-34.8
50v-10	0/3/0	<b>152.2</b>	0.3	23.3	<b>0.6</b>	-18.1/0.0/-1.3/-50.0
CMS750-4	3/0/0	<b>80.4</b>	3.7	60.8	12.4	-34.1/9.8/6.6/-3.2
a1c1s1	3/0/0	58.4	<b>0.5</b>	31.0	<b>1.0</b>	-9.6/-20.0/1.0/23.1
academictimetables	0/0/1	inf	767.5	1301.0	0.0	-/-/-/-
aflow30a	3/0/0	<b>70.9</b>	0.1	32.0	<b>1.5</b>	46.1/0.0/4.5/25.0
aflow40b	3/0/0	<b>234.4</b>	<b>0.4</b>	<b>41.4</b>	<b>6.1</b>	-11.6/-25.0/-22.7/-75.4
air04	3/0/0	<b>1.0</b>	2.6	6.6	0.0	-90.0/0.0/0.0/0.0
air05	3/0/0	<b>5.5</b>	<b>1.3</b>	<b>7.3</b>	0.0	-25.5/-38.5/-45.2/0.0
app1-1	3/0/0	<b>53.0</b>	0.5	31.7	<b>1.3</b>	-94.2/0.0/8.4/67.5
app1-2	3/0/0	43.9	<b>7.3</b>	<b>36.6</b>	<b>6.1</b>	0.0/31.8/29.3/60.1
arki001	0/0/3	3.1	<b>26.6</b>	954.5	220.1	-6.5/-22.2/-15.8/-15.3
assign1-5-8	3/0/0	<b>10.2</b>	0.1	<b>3.6</b>	0.0	-81.4/0.0/83.9/0.0
atlanta-ip	3/0/0	<b>16.0</b>	<b>13.8</b>	<b>18.5</b>	<b>0.0</b>	11.1/18.3/28.3/100.0
b1c1s1	3/0/0	<b>185.6</b>	0.5	33.7	3.6	-13.1/0.0/0.0/0.0
bab2	2/0/1	<b>18.4</b>	286.2	156.4	24.5	27.8/8.9/9.6/-4.1
bab6	3/0/0	<b>10.4</b>	<b>52.4</b>	<b>23.8</b>	<b>0.4</b>	56.1/49.8/72.9/97.4
beasleyC3	3/0/0	11.6	0.2	35.0	4.8	0.0/0.0/0.0/0.0
binkar10-1	3/0/0	<b>2.2</b>	0.1	<b>9.3</b>	0.0	45.0/0.0/40.8/0.0
blp-ar98	3/0/0	66.8	<b>2.4</b>	17.9	0.0	6.3/-16.7/-5.6/0.0
blp-ic98	3/0/0	36.3	<b>0.5</b>	<b>2.6</b>	0.0	2.7/-20.0/-15.4/0.0
bnatt400	0/0/2	0.0	179.0	775.3	0.0	-/-/-/-
bppc4-08	3/0/0	<b>38.9</b>	<b>0.4</b>	<b>23.3</b>	<b>0.0</b>	24.6/66.7/62.6/100.0
brazil3	0/3/0	<b>1078.6</b>	<b>47.8</b>	<b>33.2</b>	0.0	-41.2/-55.9/-35.5/0.0
buildingenergy	0/3/0	1.1	<b>273.1</b>	<b>5.0</b>	0.0	0.0/60.8/57.3/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.7	40.3	10.3	0.0/0.0/-0.7/-2.9
chromaticindex1024-7	3/0/0	0.0	54.2	<b>2.3</b>	0.0	0.0/1.1/23.3/0.0
chromaticindex512-7	3/0/0	0.0	43.8	2.0	0.0	0.0/2.7/0.0/0.0
cmflsp50-24-8-8	0/1/2	20.0	172.4	1020.5	297.8	-2.5/-2.8/2.8/-1.1
co-100	3/0/0	301.8	<b>3.0</b>	<b>7.0</b>	0.0	0.3/50.8/55.1/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	<b>3064.9</b>	<b>16.2</b>	<b>51.6</b>	<b>0.4</b>	10.6/-61.7/-53.5/-100.0
comp21-2idx	0/3/0	<b>547.1</b>	<b>12.3</b>	<b>56.7</b>	<b>0.6</b>	-22.0/-62.6/-55.7/-100.0
cost266-UUE	3/0/0	36.7	<b>0.2</b>	<b>13.0</b>	<b>0.0</b>	-4.4/50.0/44.7/100.0
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	1/0/2	69.1	<b>6.8</b>	436.2	51.7	-0.1/-10.3/-12.3/-4.4
csched008	3/0/0	<b>8.6</b>	<b>0.5</b>	<b>39.2</b>	<b>2.0</b>	12.2/70.6/74.2/91.7
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	20.4	<b>2.0</b>	0.0	0.0/-8.3/87.7/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>21.6</b>	<b>3.0</b>	<b>0.0</b>	-33.3/50.9/90.0/100.0
dano3mip	3/0/0	<b>14.6</b>	<b>28.1</b>	<b>11.7</b>	<b>0.0</b>	15.1/90.0/83.4/100.0
danooint	3/0/0	<b>21.8</b>	<b>0.8</b>	<b>39.6</b>	<b>4.8</b>	96.7/80.0/64.5/88.3
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	5.5	<b>0.2</b>	<b>7.0</b>	0.0	1.8/33.3/46.2/0.0
drayage-25-23	3/0/0	<b>16.4</b>	<b>0.5</b>	15.8	0.0	-37.8/-20.0/3.7/0.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0
dws008-01	0/0/3	<b>57.4</b>	<b>66.6</b>	835.5	252.5	40.1/10.7/-1.9/-6.7
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.0	1.0	0.0	0.0/9.1/0.0/0.0
enlight-hard	0/0/2	0.0	2.6	870.4	459.5	-/-/-/-
exp-1-500-5-5	3/0/0	73.6	0.1	<b>23.9</b>	0.0	2.4/0.0/11.2/0.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	853.3	<b>0.9</b>	<b>44.1</b>	<b>3.6</b>	5.9/-55.6/-54.0/-100.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	16.6	<b>2.0</b>	<b>13.5</b>	<b>0.0</b>	3.5/71.4/75.9/100.0
fiber	3/0/0	<b>79.7</b>	0.1	<b>29.3</b>	0.0	48.1/0.0/-49.1/0.0
fixnet6	3/0/0	<b>52.3</b>	0.1	31.0	1.0	-18.5/0.0/0.0/0.0

(continued)

Table A.19 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	19.3	0.1	2.9	0.0	-45.6/0.0/0.0/0.0
germanrr	0/3/0	3.0	10.0	43.2	4.9	26.8/14.5/15.0/16.9
gesa2	0/3/0	2.6	0.2	20.4	0.0	-7.7/0.0/0.0/0.0
gesa2-o	0/3/0	18.0	0.2	36.5	1.5	10.0/0.0/-2.5/0.0
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	3/0/0	223.1	0.2	62.2	16.6	67.3/33.3/40.3/48.4
gmu-35-40	3/0/0	7.4	0.1	10.0	0.0	-12.2/0.0/28.6/0.0
gmu-35-50	3/0/0	14.0	0.3	34.4	0.9	-12.9/0.0/-8.7/10.0
graph20-20-1rand	3/0/0	17.7	2.3	22.4	0.0	-20.9/43.9/28.4/100.0
graphdraw-domain	0/3/0	50.1	0.2	28.4	0.9	-42.5/33.3/53.2/91.3
h80x6320d	3/0/0	18.4	1.2	32.0	1.9	16.4/0.0/0.0/0.0
harp2	3/0/0	11.9	0.1	12.7	0.0	4.0/0.0/0.0/0.0
highschool1-aigio	0/3/0	inf	1353.1	46.6	0.3	0.0/-49.1/-67.2/-100.0
hypothyroid-k1	3/0/0	0.0	4.6	1.0	0.0	0.0/4.2/0.0/0.0
ic97p	0/0/3	14.2	4.3	777.6	170.0	7.8/15.7/12.3/17.2
ic97t	0/1/2	13.1	3.8	1133.4	279.0	-5.3/2.6/10.5/10.3
icir97p	0/0/3	20.1	14.6	832.0	161.3	12.2/32.4/27.0/25.2
icir97t	0/3/0	14.4	3.5	155.4	85.1	8.3/20.5/26.2/33.9
irish-electricity	3/0/0	7.6	11.4	10.1	0.0	-21.1/41.2/58.3/100.0
irp	3/0/0	0.4	0.4	4.3	0.0	89.5/-25.0/-20.9/0.0
istanbul-no-cutoff	3/0/0	25.4	6.3	22.0	0.0	29.4/1.6/0.0/0.0
k1mushroom	3/0/0	18.2	40.9	1.0	0.0	0.0/-2.7/0.0/0.0
lectsched-5-obj	0/0/3	2823.5	116.5	1244.4	6.6	-20.5/-27.9/-27.0/5.7
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	97.8	0.7	50.0	18.3	85.5/36.4/44.4/67.7
lotsize	2/0/1	203.2	1.8	135.4	45.7	-65.2/-72.2/-66.8/-77.0
mad	3/0/0	10466.5	0.2	27.0	0.0	15.3/-50.0/-45.6/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	40.4	30.3	38.8	4.5	9.6/39.3/-7.7/-28.9
map16715-04	3/0/0	93.0	42.8	35.5	2.5	-4.1/24.8/23.3/72.5
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	126.3	0.1	19.0	0.0	73.5/50.0/78.9/100.0
mas76	0/3/0	18.2	0.1	12.3	0.0	82.8/50.0/86.4/100.0
mc11	3/0/0	90.0	0.4	42.3	12.0	16.8/0.0/0.7/2.4
mcsched	3/0/0	53.5	0.5	2.6	0.0	-75.9/0.0/27.8/0.0
mik-250-20-75-4	0/3/0	23.6	0.1	17.2	0.8	61.4/50.0/55.1/82.2
nilo-v12-6-r2-40-1	3/0/0	91.5	0.8	38.6	6.3	39.1/11.1/8.1/47.5
misc07	3/0/0	45.1	0.1	18.6	0.0	-36.6/0.0/7.5/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	3.2	0.3	15.5	0.0	77.1/0.0/20.9/0.0
modglob	3/0/0	16.0	0.1	20.3	0.0	84.9/0.0/35.1/100.0
momentum1	0/3/0	219.1	39.0	531.6	306.9	-11.7/1.3/4.7/13.1
msc98-ip	3/0/0	15.4	5.5	27.2	0.6	0.6/12.7/11.4/0.0
mushroom-best	0/3/0	9.98e06	16.8	57.7	5.3	-8.1/-19.0/-30.7/-67.9
mzzv11	0/3/0	23.8	3.3	14.6	0.0	-15.5/21.4/24.4/0.0
mzzv42z	0/3/0	32.1	2.5	11.2	0.0	-3.4/49.0/52.9/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	13.2	0.3	20.4	0.0	-28.8/0.0/0.0/0.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	13.4	2.7	15.6	0.0	-93.3/44.9/40.9/100.0
neos-1171737	3/0/0	8.4	0.8	9.7	0.0	-53.6/50.0/67.2/100.0
neos-1354092	0/3/0	12.8	118.4	25.9	0.0	29.3/32.8/31.1/0.0
neos-1445765	3/0/0	35.3	0.7	6.2	0.0	0.3/12.5/-9.7/0.0
neos-1456979	0/2/1	140.4	19.0	210.7	32.2	6.3/53.0/54.4/66.6
neos-1582420	0/3/0	52.2	0.7	34.2	1.3	24.3/53.3/57.0/86.2

(continued)

Table A.19 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-2657525-crna	0/3/0	1032.2	0.2	<b>37.4</b>	<b>2.5</b>	-1.5/0.0/10.5/-20.0
neos-2746589-doon	0/2/1	<b>48.6</b>	129.8	219.4	22.4	-28.2/6.0/11.6/28.4
neos-2978193-inde	3/0/0	<b>2.1</b>	<b>0.3</b>	<b>5.5</b>	0.0	36.4/-33.3/-58.2/0.0
neos-2987310-joes	2/1/0	0.3	10.1	54.3	14.8	0.0/-5.9/0.0/0.0
neos-3004026-krka	0/0/3	0.0	109.2	1285.7	3.6	0.0/-0.2/0.0/0.0
neos-3024952-loue	0/0/3	836.0	<b>106.5</b>	1864.3	25.1	-2.7/-25.0/-24.1/9.7
neos-3046615-murg	0/3/0	<b>6908.7</b>	0.2	<b>110.8</b>	<b>86.7</b>	36.6/0.0/-14.9/-24.3
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	129.3	<b>402.9</b>	974.6	0.6	-6.5/12.1/11.1/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>14.3</b>	814.2	1.2	0.0/21.9/22.8/-8.3
neos-3402294-bobin	2/1/0	<b>156.3</b>	<b>17.7</b>	<b>13.9</b>	0.0	63.6/11.9/27.2/0.0
neos-3555904-turama	3/0/0	<b>4.3</b>	<b>150.4</b>	34.8	<b>0.9</b>	-53.5/-48.0/-9.8/-55.6
neos-3627168-kasai	3/0/0	<b>1.1</b>	0.1	22.0	<b>0.3</b>	26.7/0.0/-7.3/-100.0
neos-3656078-kumeu	0/0/3	<b>25.1</b>	136.4	978.4	0.4	18.5/2.8/6.1/55.6
neos-3754480-nidda	3/0/0	<b>13233.7</b>	<b>0.1</b>	<b>18.3</b>	<b>0.0</b>	-97.2/50.0/73.0/100.0
neos-4300652-rahue	0/0/3	<b>327.8</b>	<b>631.5</b>	738.2	0.4	-18.9/-34.6/-52.0/-25.0
neos-4338804-snowy	0/3/0	<b>470.4</b>	<b>0.7</b>	<b>89.8</b>	<b>23.0</b>	99.6/12.5/10.6/17.9
neos-4387871-tavua	0/1/2	<b>352.1</b>	25.3	884.5	457.1	53.4/-9.5/-9.3/-6.5
neos-4413714-turia	3/0/0	<b>18.6</b>	<b>38.7</b>	<b>35.6</b>	<b>2.7</b>	57.6/51.6/55.3/79.2
neos-4532248-waihi	0/0/3	949.4	<b>576.7</b>	730.0	72.7	0.0/-15.2/-39.8/-50.3
neos-4647030-tutaki	3/0/0	<b>97.0</b>	<b>13.4</b>	<b>13.0</b>	0.0	-77.3/23.4/26.6/0.0
neos-4722843-widden	0/3/0	<b>121.0</b>	50.0	<b>82.9</b>	<b>22.5</b>	38.8/9.3/10.3/12.1
neos-4738912-atrato	0/3/0	<b>9.5</b>	<b>0.4</b>	<b>18.7</b>	0.0	20.8/-25.0/-33.7/0.0
neos-4763324-toguru	3/0/0	<b>105.2</b>	<b>35.4</b>	<b>40.7</b>	<b>9.6</b>	-43.7/-40.4/-41.8/-100.0
neos-4954672-berkel	3/0/0	53.4	0.1	<b>19.9</b>	<b>0.0</b>	2.4/0.0/37.8/100.0
neos-5049753-cuanza	0/2/1	<b>61.3</b>	<b>1122.4</b>	417.7	89.7	18.9/-31.4/-22.0/-19.7
neos-5052403-cygnat	3/0/0	<b>0.3</b>	39.5	<b>2.0</b>	0.0	76.9/6.2/13.0/0.0
neos-5093327-huahum	0/3/0	<b>1299.4</b>	<b>18.6</b>	<b>152.4</b>	<b>115.3</b>	-29.7/-28.0/-20.8/-24.9
neos-5104907-jarama	0/0/2	152.8	3104.2	793.8	46.7	-/-/-/-
neos-5107597-kakapo	3/0/0	<b>14034.4</b>	<b>1.6</b>	<b>107.9</b>	<b>76.6</b>	64.3/11.1/12.5/19.3
neos-5114902-kasavu	1/0/0	63.7	3094.1	122.0	32.0	-/-/-/-
neos-5188808-nattai	3/0/0	3783.0	<b>14.4</b>	<b>64.0</b>	<b>11.7</b>	5.7/-60.4/-58.3/-100.0
neos-5195221-niemur	3/0/0	<b>633.5</b>	<b>14.3</b>	<b>33.6</b>	<b>1.5</b>	17.5/-48.3/-44.3/-100.0
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	<b>251.6</b>	6.4	18.6	<b>0.4</b>	-11.3/0.0/3.6/42.9
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	0/3/0	<b>3.44e05</b>	<b>133.3</b>	<b>90.7</b>	<b>29.0</b>	-14.0/-22.5/-23.6/-28.6
neos-860300	3/0/0	<b>77.8</b>	<b>1.4</b>	<b>16.8</b>	0.0	-26.7/-71.4/-76.2/0.0
neos-873061	3/0/0	<b>39.7</b>	27.7	31.7	1.6	35.1/-7.2/0.0/0.0
neos-911970	3/0/0	<b>230.5</b>	0.2	<b>36.3</b>	<b>1.3</b>	-42.7/0.0/27.4/78.3
neos-933966	3/0/0	<b>3.5</b>	<b>2.9</b>	<b>6.2</b>	0.0	98.4/-44.8/34.0/0.0
neos-950242	3/0/0	<b>194.2</b>	<b>12.6</b>	<b>31.5</b>	<b>1.3</b>	-33.9/-46.8/-30.8/-69.2
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	3/0/0	<b>1.5</b>	<b>10.2</b>	<b>26.4</b>	<b>0.7</b>	34.8/49.5/57.4/66.7
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<b>1.1</b>	<b>6.9</b>	876.2	6.1	21.4/25.8/25.0/-57.4
neos17	3/0/0	<b>216.6</b>	<b>0.1</b>	35.0	<b>4.0</b>	25.4/50.0/-9.4/-60.0
neos20	0/0/3	50.0	<b>7.9</b>	876.1	68.3	-8.6/19.4/25.9/16.1
neos5	3/0/0	40.4	0.1	<b>3.2</b>	0.0	2.9/0.0/15.8/0.0
neos7	0/3/0	9.9	0.2	<b>15.5</b>	<b>0.3</b>	10.0/0.0/38.0/-100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>19.2</b>	<b>2.5</b>	<b>10.6</b>	0.0	49.9/41.9/58.8/0.0
netdiversion	3/0/0	<b>101.5</b>	<b>256.1</b>	<b>17.0</b>	0.0	-14.9/-70.8/-43.5/0.0
nexp-150-20-8-5	3/0/0	145.9	<b>0.3</b>	<b>3.0</b>	0.0	0.0/40.0/57.1/0.0
nh97p	0/0/3	<b>8.3</b>	<b>12.1</b>	988.8	209.0	18.6/11.0/9.5/19.3
nh97t	0/1/2	11.2	<b>11.3</b>	975.2	309.6	-5.4/11.7/10.7/5.2
noswot	0/3/0	<b>11.7</b>	0.1	<b>17.5</b>	<b>0.6</b>	-17.9/0.0/49.0/53.8
ns1116954	1/1/1	0.0	465.7	467.3	3.2	0.0/1.3/0.0/0.0
ns1208400	0/2/1	0.0	95.8	421.7	0.0	0.0/-5.9/-6.2/100.0
ns1644855	3/0/0	<b>13.8</b>	<b>488.2</b>	<b>40.3</b>	<b>4.9</b>	-96.4/-20.0/-14.4/-65.3

(continued)

Table A.19 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
ns1760995	3/0/0	<b>11.0</b>	<b>20.9</b>	<b>18.7</b>	<b>0.3</b>	26.2/75.3/76.8/89.7
ns1830653	1/2/0	<b>481.8</b>	<b>9.7</b>	<b>181.2</b>	<b>5.2</b>	-65.9/-54.6/-67.5/-80.8
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-idx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.6	<b>0.1</b>	<b>4.0</b>	0.0	-8.3/66.7/78.9/0.0
nursesched-medium-hint03	0/3/0	<b>1027.1</b>	<b>67.3</b>	<b>34.6</b>	<b>0.8</b>	-23.4/-79.3/-67.1/-100.0
nursesched-sprint02	0/3/0	<b>31.8</b>	<b>4.1</b>	<b>21.6</b>	0.0	42.4/-53.7/-56.9/0.0
nw04	3/0/0	<b>16.4</b>	<b>4.6</b>	<b>19.6</b>	0.0	-76.2/-56.5/-59.2/0.0
opm2-z10-s4	3/0/0	94.2	27.2	1.0	0.0	0.0/0.4/0.0/0.0
opt1217	3/0/0	<b>10.1</b>	0.1	<b>20.3</b>	<b>0.0</b>	-22.8/0.0/44.1/100.0
p200x1188c	3/0/0	<b>4.4</b>	0.2	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	<b>72.4</b>	0.1	5.0	0.0	11.8/0.0/0.0/0.0
peg-solitaire-a3	0/0/1	0.0	364.5	760.0	55.0	-/-/-/-
pg	3/0/0	<b>8.7</b>	<b>0.1</b>	<b>31.3</b>	<b>1.3</b>	43.9/66.7/39.5/93.2
pg5-34	3/0/0	<b>13.1</b>	<b>0.2</b>	<b>28.6</b>	<b>0.3</b>	-45.8/50.0/45.0/97.8
physiciansched3-3	3/0/0	<b>206.8</b>	<b>43.3</b>	<b>92.1</b>	<b>3.8</b>	-95.8/20.6/-50.1/-73.7
physiciansched6-2	1/1/1	<b>4.3</b>	<b>39.7</b>	313.6	19.7	12.2/53.0/57.6/43.4
piperout-08	0/0/3	<b>234.0</b>	<b>61.8</b>	1483.3	24.3	40.7/10.7/13.3/27.0
piperout-27	0/0/3	<b>383.8</b>	<b>59.1</b>	1089.4	25.4	-40.5/10.5/9.0/-30.7
pk1	3/0/0	<b>788.2</b>	<b>0.1</b>	<b>35.3</b>	<b>1.6</b>	33.9/50.0/39.1/82.0
pp08a	3/0/0	<b>52.4</b>	0.1	<b>11.6</b>	0.0	10.3/0.0/25.6/0.0
pp08aCUTS	3/0/0	<b>26.8</b>	0.1	11.3	0.0	23.6/0.0/5.8/0.0
proteindesign121hz512p9	0/2/1	<b>9.9</b>	<b>59.2</b>	272.0	8.4	-75.8/-91.6/-91.0/-96.4
proteindesign122trx11p8	0/1/2	<b>4.1</b>	<b>47.9</b>	215.2	5.1	-73.2/-97.9/-98.1/-100.0
protfold	3/0/0	67.1	<b>5.4</b>	<b>33.1</b>	0.0	-1.6/35.7/12.4/0.0
qap10	3/0/0	<b>5.9</b>	<b>16.9</b>	<b>3.0</b>	0.0	69.6/-18.9/-33.3/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	244.2	0.5	26.9	<b>0.3</b>	-1.6/0.0/-5.9/-100.0
rB10-011001	3/0/0	203.8	0.5	27.5	<b>0.3</b>	0.1/0.0/-4.4/-100.0
rB11-010000	3/0/0	265.7	1.3	30.3	<b>0.3</b>	8.0/0.0/-1.0/50.0
rB11-110001	3/0/0	<b>162.7</b>	2.6	25.7	<b>0.0</b>	21.6/0.0/-9.3/100.0
rB12-111111	0/0/3	<b>75.3</b>	<b>61.5</b>	771.7	1.3	16.2/-24.6/-25.5/59.4
rC10-001000	3/0/0	<b>192.5</b>	0.2	27.6	0.0	30.0/0.0/1.1/0.0
rC10-100001	2/1/0	444.9	4.7	95.7	<b>0.6</b>	-8.2/4.1/5.7/25.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	337.5	<b>4.5</b>	<b>30.2</b>	0.8	-4.7/11.8/17.0/0.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>181.3</b>	<b>1.6</b>	63.7	<b>4.2</b>	-16.1/11.1/6.7/-14.3
radiationm40-10-02	0/3/0	<b>1647.9</b>	16.9	<b>182.8</b>	<b>19.9</b>	-73.8/-4.1/-21.3/-54.8
rail01	3/0/0	33.6	<b>1480.0</b>	<b>15.9</b>	0.0	-7.7/-13.5/-25.2/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<b>20.5</b>	0.3	22.8	0.3	-19.0/0.0/0.0/0.0
rd-rplusc-21	0/0/3	56.8	34.9	850.0	364.1	2.2/3.6/1.9/-1.0
reblock115	3/0/0	12.1	<b>0.9</b>	<b>35.3</b>	<b>1.7</b>	-7.4/43.8/36.3/72.6
rmatr100-p10	3/0/0	<b>2.6</b>	<b>0.9</b>	<b>4.3</b>	0.0	91.2/-33.3/-46.5/0.0
rmatr200-p5	3/0/0	<b>17.1</b>	<b>39.7</b>	<b>10.3</b>	0.0	12.3/-64.5/-80.6/0.0
rocl-4-11	0/0/3	<b>54.9</b>	<b>17.1</b>	717.2	78.6	20.7/19.3/23.1/24.3
rocll-5-11	1/1/1	90.6	<b>24.5</b>	436.6	129.7	-0.2/-65.7/-64.2/-59.4
roi2alpha3n4	3/0/0	<b>45.5</b>	<b>21.0</b>	<b>21.0</b>	<b>0.0</b>	27.1/36.9/38.8/100.0
roi5alpha10n8	3/0/0	65.5	<b>204.7</b>	<b>15.0</b>	0.0	-8.2/54.2/48.3/0.0
roll3000	0/3/0	<b>33.1</b>	<b>0.8</b>	<b>37.6</b>	<b>2.6</b>	-20.8/27.3/22.3/42.2
rou	0/3/0	<b>39.7</b>	0.2	38.9	<b>3.2</b>	19.8/0.0/-9.5/-46.9
s100	3/0/0	<b>0.1</b>	<b>226.4</b>	7.0	0.0	94.1/25.2/-5.7/0.0
s250r10	3/0/0	<b>0.7</b>	48.9	<b>3.0</b>	0.0	-85.7/8.4/-33.3/0.0
satellites2-40	3/0/0	257.4	<b>315.6</b>	33.1	<b>1.2</b>	-4.7/-86.0/5.2/55.6
satellites2-60-fs	3/0/0	<b>176.8</b>	<b>350.2</b>	<b>39.8</b>	<b>4.6</b>	-49.4/-93.5/-12.3/-41.3
savsched1	0/3/0	<b>11.6</b>	<b>162.9</b>	<b>9.9</b>	0.0	-31.9/14.3/19.5/0.0
sct2	3/0/0	31.3	0.6	26.5	<b>0.7</b>	-6.7/0.0/-1.5/-14.3
set1ch	3/0/0	<b>69.8</b>	0.1	31.0	1.0	18.5/0.0/0.0/0.0

(continued)

Table A.19 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<b>3.2</b>	<b>1.5</b>	<b>2.9</b>	0.0	-56.3/44.4/61.8/0.0
sing326	3/0/0	<b>37.9</b>	22.8	31.3	<b>1.0</b>	-72.0/7.7/7.9/37.5
sing44	3/0/0	<b>11.4</b>	<b>21.8</b>	<b>31.0</b>	<b>0.3</b>	-35.1/17.4/19.5/92.1
snp-02-004-104	0/3/0	<b>111.2</b>	21.4	32.7	<b>1.0</b>	-98.5/-7.9/2.7/47.4
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.3	1.3	0.0/0.0/0.0/0.0
sp97ar	3/0/0	25.4	0.9	2.2	0.0	4.5/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	96.2	<b>34.6</b>	<b>3.0</b>	0.0	2.4/44.3/76.9/0.0
square41	0/2/0	11.7	3374.5	27.5	0.0	-/-/-/-
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>191.3</b>	119.4	12.7	0.0	-11.0/-7.8/6.6/0.0
supportcase12	0/3/0	<b>14.8</b>	<b>3.7</b>	<b>3.8</b>	0.0	-87.8/74.7/81.9/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>59.9</b>	0.2	<b>80.0</b>	<b>50.3</b>	99.4/0.0/10.8/20.5
supportcase33	0/3/0	65.9	<b>18.0</b>	<b>167.8</b>	<b>41.6</b>	-2.1/-23.3/-27.7/-65.1
supportcase40	3/0/0	16.7	<b>1.8</b>	<b>8.3</b>	0.0	5.1/57.1/50.0/0.0
supportcase42	0/3/0	<b>32.7</b>	<b>10.8</b>	<b>31.0</b>	<b>1.0</b>	-25.4/-61.1/-62.6/-100.0
supportcase6	3/0/0	<b>2.5</b>	<b>21.1</b>	<b>21.4</b>	0.0	-84.0/-37.0/-43.9/0.0
supportcase7	3/0/0	<b>24.7</b>	<b>12.7</b>	<b>40.6</b>	<b>5.9</b>	-42.1/-34.6/-36.0/-100.0
swath	0/3/0	<b>202.0</b>	14.5	198.1	63.9	-10.1/-6.9/-5.2/-6.7
swath1	3/0/0	<b>27.3</b>	<b>1.9</b>	57.7	<b>13.9</b>	54.8/17.4/7.2/11.5
swath3	3/0/0	<b>24.4</b>	<b>2.0</b>	<b>58.8</b>	<b>13.5</b>	26.5/-25.0/-27.0/-76.3
t1717	3/0/0	168.5	115.9	39.5	0.0	6.0/8.2/9.2/0.0
tbfp-network	3/0/0	<b>15.9</b>	<b>20.1</b>	<b>22.9</b>	0.0	92.0/10.3/-38.9/0.0
thor50dday	3/0/0	234.3	<b>9.1</b>	<b>30.1</b>	<b>3.4</b>	9.1/-20.9/-18.6/-50.0
timtab1	0/3/0	<b>71.6</b>	0.6	<b>137.7</b>	<b>51.1</b>	-22.5/0.0/-17.4/-45.4
timtab2	0/0/3	<b>82.5</b>	<b>9.4</b>	1281.3	477.4	-10.8/-38.3/-38.2/-43.3
tr12-30	3/0/0	74.9	0.2	31.3	<b>1.3</b>	-2.7/0.0/1.3/18.8
traininstance2	0/3/0	<b>476.6</b>	<b>2.1</b>	<b>422.6</b>	<b>54.5</b>	-48.9/36.4/34.9/20.6
traininstance6	0/2/1	<b>195.8</b>	<b>1.0</b>	221.7	34.0	57.6/16.7/27.5/19.2
trento1	3/0/0	<b>39.0</b>	<b>25.9</b>	<b>20.7</b>	0.0	79.2/-69.1/-55.1/0.0
triptim1	0/3/0	0.1	22.8	4.0	0.0	0.0/2.1/0.0/0.0
uccase12	3/0/0	<b>1.3</b>	9.5	14.3	0.0	31.6/7.8/8.3/0.0
uccase9	2/0/1	<b>2097.8</b>	<b>40.6</b>	135.4	39.4	62.6/29.9/28.6/46.0
uct-subprob	3/0/0	<b>14.9</b>	<b>0.3</b>	<b>4.6</b>	0.0	-16.8/50.0/40.3/0.0
unitcal-7	0/0/3	<b>36.0</b>	144.5	1054.4	188.1	-25.6/-4.7/-6.0/-22.4
var-smallemergy-m6j6	3/0/0	<b>43.4</b>	<b>11.4</b>	<b>31.0</b>	<b>1.0</b>	83.1/52.5/54.1/90.1
vpm2	3/0/0	44.4	0.1	20.4	0.0	1.3/0.0/0.0/0.0
wachplan	0/3/0	0.0	<b>1.8</b>	<b>19.7</b>	<b>1.7</b>	0.0/40.0/25.7/-100.0
Geom. means		(270 instances)	(230 instances)			
FP		46.0	5.3	16.6	1.3	
FP+(c)		<b>43.9</b>	5.3	<b>14.5</b>	<b>1.0</b>	

Table A.20.: Performance of FP+( $\Delta$ )

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	2/1/0	<b>6.3</b>	<b>2.6</b>	<b>32.7</b>	<b>0.6</b>	47.9/78.7/79.5/50.0
30n20b8	0/3/0	<b>843.9</b>	<b>3.9</b>	<b>125.0</b>	<b>22.4</b>	-45.2/31.6/25.1/22.5
50v-10	0/3/0	134.5	0.3	<b>19.1</b>	0.3	-7.3/0.0/17.0/0.0
CMS750-4	3/0/0	<b>62.8</b>	4.2	64.9	<b>15.9</b>	-15.6/-2.4/0.3/-24.5
a1c1s1	3/0/0	<b>82.6</b>	<b>0.6</b>	32.0	<b>2.0</b>	-36.1/-33.3/-2.2/-35.0
academictimetables-small	0/0/2	inf	560.6	795.5	0.0	-/-/-/-
aflow30a	3/0/0	122.9	0.1	32.3	<b>1.5</b>	6.6/0.0/3.6/25.0
aflow40b	3/0/0	<b>382.5</b>	0.3	<b>24.5</b>	<b>1.2</b>	-45.8/0.0/23.4/20.0
air04	3/0/0	<b>4.3</b>	2.5	<b>13.4</b>	0.0	-97.7/3.8/-50.7/0.0

(continued)



Table A.20 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
air05	3/0/0	<b>14.5</b>	<b>1.5</b>	<b>13.9</b>	0.0	-71.7/-46.7/-71.2/0.0
app1-1	3/0/0	3.1	0.5	34.2	<b>3.4</b>	0.0/0.0/1.2/15.0
app1-2	3/0/0	43.9	<b>12.5</b>	<b>61.7</b>	<b>23.1</b>	0.0/-14.4/-16.0/-33.8
arki001	0/0/3	2.8	<b>34.1</b>	1269.1	287.8	3.4/-39.3/-36.6/-35.2
assign1-5-8	3/0/0	<b>1.7</b>	0.1	21.0	0.0	10.5/0.0/5.8/0.0
atlanta-ip	3/0/0	<b>14.7</b>	<b>14.7</b>	<b>17.0</b>	<b>0.0</b>	18.3/13.0/34.1/100.0
b1c1s1	3/0/0	<b>195.4</b>	<b>0.6</b>	34.0	4.0	-17.5/-16.7/-0.9/-10.0
bab2	2/1/0	<b>40.2</b>	<b>249.9</b>	149.6	23.3	-36.6/20.4/13.5/0.9
bab6	1/0/2	<b>17.8</b>	<b>306.2</b>	400.1	142.2	24.9/-65.9/-78.1/-89.2
beasleyC3	3/0/0	11.3	0.2	35.0	4.8	2.6/0.0/0.0/0.0
binkar10-1	3/0/0	3.9	0.1	<b>9.3</b>	0.0	2.5/0.0/40.8/0.0
blp-ar98	3/0/0	68.0	1.9	15.3	0.0	4.6/5.0/9.5/0.0
blp-ic98	3/0/0	36.9	0.4	<b>2.7</b>	0.0	1.1/0.0/-18.5/0.0
bnatt400	0/0/3	0.0	<b>254.6</b>	924.2	0.0	0.0/-16.4/-8.3/0.0
bppc4-08	3/0/0	<b>28.2</b>	<b>0.6</b>	<b>27.2</b>	<b>0.0</b>	45.3/50.0/56.3/100.0
brazil3	0/3/0	<b>978.5</b>	<b>39.3</b>	<b>32.0</b>	0.0	-35.2/-46.3/-33.1/0.0
buildingenergy	0/3/0	<b>0.9</b>	<b>122.7</b>	<b>4.0</b>	0.0	18.2/82.4/65.8/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	<i>inf</i>	2.5	<b>30.0</b>	<b>0.0</b>	-100.0/7.4/25.0/100.0
chromaticindex1024-7	3/0/0	0.0	60.0	<b>6.0</b>	0.0	0.0/-8.7/-50.0/0.0
chromaticindex512-7	3/0/0	0.0	<b>71.0</b>	<b>6.3</b>	0.0	0.0/-36.6/-68.3/0.0
cmflsp50-24-8-8	1/0/2	18.4	<b>47.3</b>	301.7	62.7	5.6/71.8/71.3/78.7
co-100	3/0/0	302.2	6.1	15.5	0.0	0.2/0.0/0.6/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	3531.5	5.8	21.7	0.0	-3.0/6.5/9.6/0.0
comp21-2idx	0/3/0	<b>378.5</b>	4.3	23.3	0.0	11.3/6.5/7.2/0.0
cost266-UUE	3/0/0	37.0	0.4	23.6	0.3	-5.1/0.0/-0.4/0.0
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/0/3	<b>61.4</b>	<b>10.3</b>	844.6	147.9	11.0/-40.8/-54.7/-66.6
csched008	2/1/0	9.4	<b>1.5</b>	<b>131.6</b>	<b>20.2</b>	4.1/11.8/13.4/15.8
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	18.1	<b>4.0</b>	0.0	0.0/3.2/75.3/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>21.1</b>	<b>13.0</b>	<b>0.0</b>	-33.3/52.0/56.8/100.0
dano3mip	3/0/0	<b>14.7</b>	<b>240.9</b>	<b>62.0</b>	<b>14.3</b>	14.5/14.0/12.2/21.9
danooint	3/0/0	<b>19.3</b>	<b>0.9</b>	<b>32.9</b>	<b>1.4</b>	97.0/77.5/70.5/96.6
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>19.2</b>	0.3	13.0	0.0	-70.8/0.0/0.0/0.0
drayage-25-23	3/0/0	<b>6.7</b>	<b>0.2</b>	<b>4.0</b>	0.0	34.3/50.0/75.6/0.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0
dws008-01	0/0/3	<b>60.0</b>	<b>59.7</b>	755.5	220.5	37.4/20.0/7.8/6.4
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.0	1.0	0.0	0.0/9.1/0.0/0.0
enlight-hard	0/0/1	0.0	4.3	1032.0	528.0	-/-/-/-
exp-1-500-5-5	3/0/0	<b>145.0</b>	0.1	<b>15.5</b>	0.0	-48.0/0.0/42.4/0.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>719.4</b>	<b>0.2</b>	<b>10.1</b>	0.0	20.7/50.0/50.2/0.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>11.1</b>	6.9	<b>38.0</b>	<b>2.5</b>	35.5/1.4/32.1/45.7
fiber	3/0/0	160.5	0.1	<b>4.0</b>	0.0	-4.3/0.0/73.2/0.0
fixnet6	3/0/0	<b>60.6</b>	0.1	31.0	1.0	-29.7/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>14.0</b>	0.1	<b>5.9</b>	<b>0.3</b>	-25.0/0.0/-50.8/-100.0
germanrr	0/3/0	4.2	<b>10.3</b>	51.9	6.4	-2.4/12.0/-2.1/-7.8
gesa2	0/3/0	2.6	0.2	20.4	0.0	-7.7/0.0/0.0/0.0
gesa2-o	0/3/0	<b>18.0</b>	0.2	36.5	1.5	10.0/0.0/-2.5/0.0
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	<b>0.5</b>	1.0	0.0	0.0/16.7/0.0/0.0
glass4	3/0/0	<b>967.0</b>	0.3	113.3	<b>36.4</b>	-29.5/0.0/-8.0/-11.5
gmu-35-40	3/0/0	<b>7.4</b>	0.1	<b>4.0</b>	0.0	-12.2/0.0/71.4/0.0
gmu-35-50	3/0/0	<b>16.3</b>	<b>0.2</b>	<b>20.2</b>	0.9	-25.2/33.3/35.7/10.0
graph20-20-1rand	3/0/0	<b>39.5</b>	3.8	<b>28.0</b>	<b>0.0</b>	-64.6/7.3/10.5/100.0

(continued)

Table A.20 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
graphdraw-domain	0/3/0	31.0	<b>0.2</b>	<b>44.6</b>	<b>4.8</b>	-7.1/33.3/26.5/53.8
h80x6320d	3/0/0	22.9	1.2	32.0	1.9	-3.9/0.0/0.0/0.0
harp2	3/0/0	13.6	0.1	<b>17.9</b>	0.0	-8.8/0.0/-29.1/0.0
highschool1-aigio	0/3/0	inf	<b>899.7</b>	<b>25.6</b>	<b>0.3</b>	0.0/-23.5/-40.2/-100.0
hypothyroid-k1	3/0/0	0.0	4.6	1.0	0.0	0.0/4.2/0.0/0.0
ic97p	0/1/2	15.0	<b>4.2</b>	733.4	176.8	2.6/17.6/17.3/13.9
ic97t	0/1/2	12.1	<b>2.9</b>	909.5	230.4	2.4/25.6/28.2/26.0
icir97p	0/0/3	<b>19.1</b>	<b>15.1</b>	858.6	146.8	16.6/30.1/24.7/31.9
icir97t	0/3/0	<b>6.3</b>	<b>2.2</b>	<b>110.6</b>	<b>52.2</b>	59.9/50.0/47.5/59.5
irish-electricity	3/0/0	<b>6.7</b>	<b>12.5</b>	<b>9.3</b>	<b>0.0</b>	-10.4/35.6/61.6/100.0
irp	3/0/0	<b>6.0</b>	<b>0.2</b>	<b>2.3</b>	0.0	-36.7/33.3/32.4/0.0
istanbul-no-cutoff	3/0/0	<b>24.4</b>	<b>3.6</b>	<b>9.9</b>	0.0	32.2/43.8/55.0/0.0
k1mushroom	3/0/0	18.2	39.7	1.0	0.0	0.0/0.3/0.0/0.0
lectsched-5-obj	0/0/3	<b>2519.3</b>	93.3	976.1	12.1	-10.9/-10.0/-6.9/-42.1
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>329.7</b>	1.2	91.3	58.3	51.1/-8.3/-1.4/-2.9
lotsize	3/0/0	<b>115.5</b>	0.5	<b>50.1</b>	<b>12.0</b>	-38.8/0.0/-10.4/-12.5
mad	3/0/0	<b>7751.1</b>	0.1	<b>6.0</b>	0.0	37.3/0.0/59.2/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	48.7	<b>33.1</b>	<b>19.3</b>	<b>0.0</b>	-8.2/33.7/46.1/100.0
map16715-04	3/0/0	<b>78.1</b>	<b>39.3</b>	<b>16.6</b>	<b>0.0</b>	12.4/30.9/64.1/100.0
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>104.9</b>	0.2	88.7	14.6	78.0/0.0/1.4/0.0
mas76	0/3/0	<b>36.3</b>	0.2	89.0	<b>16.4</b>	65.7/0.0/1.9/23.7
mc11	3/0/0	114.3	0.4	42.7	12.6	-5.3/0.0/-0.2/-2.4
mcsched	3/0/0	<b>38.3</b>	0.5	<b>5.5</b>	0.0	-66.3/0.0/-34.5/0.0
mik-250-20-75-4	0/3/0	<b>0.5</b>	<b>0.1</b>	<b>8.6</b>	<b>0.0</b>	99.2/50.0/77.5/100.0
milo-v12-6-r2-40-1	3/0/0	138.2	0.9	42.3	12.3	8.1/0.0/-0.7/-2.4
misc07	3/0/0	<b>37.0</b>	0.1	<b>17.0</b>	0.0	-22.7/0.0/15.4/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>7.5</b>	<b>0.2</b>	<b>8.3</b>	0.0	46.4/33.3/57.7/0.0
modglob	3/0/0	<b>25.2</b>	0.1	29.0	<b>0.3</b>	76.2/0.0/7.3/76.9
momentum1	0/2/1	208.4	<b>48.8</b>	662.5	382.3	-7.2/-19.1/-15.8/-7.6
msc98-ip	3/0/0	<b>9.0</b>	<b>5.3</b>	<b>25.4</b>	0.6	41.9/15.9/17.3/0.0
mushroom-best	0/3/0	<b>1.17e05</b>	<b>9.8</b>	36.4	<b>3.4</b>	98.7/27.9/9.0/-50.0
mzzv11	0/3/0	<b>29.4</b>	<b>3.2</b>	<b>11.6</b>	0.0	-31.6/23.8/39.9/0.0
mzzv42z	0/3/0	<b>25.3</b>	<b>3.0</b>	<b>11.3</b>	<b>0.0</b>	18.4/38.8/52.5/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>13.0</b>	0.3	20.4	0.0	-27.7/0.0/0.0/0.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>16.0</b>	<b>2.0</b>	<b>7.7</b>	<b>0.0</b>	-94.4/59.2/70.8/100.0
neos-1171737	3/0/0	<b>9.8</b>	<b>0.7</b>	<b>7.2</b>	<b>0.0</b>	-60.2/56.3/75.7/100.0
neos-1354092	0/3/0	16.6	<b>154.1</b>	<b>33.2</b>	<b>0.3</b>	8.3/12.6/11.7/-100.0
neos-1445765	3/0/0	<b>26.4</b>	<b>0.6</b>	<b>5.0</b>	0.0	25.4/25.0/10.7/0.0
neos-1456979	0/2/1	<b>122.3</b>	<b>13.9</b>	162.5	34.2	18.4/65.6/64.9/64.6
neos-1582420	0/3/0	70.3	<b>2.6</b>	<b>122.9</b>	<b>15.3</b>	-1.8/-42.3/-35.3/-38.6
neos-2657525-crna	0/3/0	1036.8	<b>0.4</b>	<b>80.1</b>	<b>3.2</b>	-2.0/-50.0/-47.8/-37.5
neos-2746589-doon	0/0/3	<b>15.9</b>	<b>1542.0</b>	722.1	21.9	54.4/-91.0/-65.6/30.0
neos-2978193-inde	3/0/0	3.3	0.2	2.3	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	2/1/0	0.3	10.2	54.3	14.8	0.0/-6.9/0.0/0.0
neos-3004026-krka	0/0/3	0.0	108.3	1285.7	3.6	0.0/0.6/0.0/0.0
neos-3024952-loue	0/1/2	816.3	75.6	1318.1	12.9	-0.4/5.4/6.8/53.6
neos-3046615-murg	0/3/0	<b>5816.2</b>	0.2	<b>114.8</b>	<b>90.2</b>	46.6/0.0/-17.9/-27.3
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	130.0	<b>408.1</b>	940.4	0.6	-7.0/11.0/14.2/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>16.4</b>	981.9	0.0	0.0/10.4/6.8/100.0
neos-3402294-bobin	2/1/0	<b>545.5</b>	<b>22.4</b>	19.7	0.0	-21.3/-10.3/-3.0/0.0

(continued)

Table A.20 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-3555904-turama	3/0/0	<b>4.3</b>	<b>44.7</b>	<b>21.2</b>	<b>0.0</b>	-53.5/42.8/32.5/100.0
neos-3627168-kasai	3/0/0	1.6	0.1	20.4	0.0	-6.3/0.0/0.0/0.0
neos-3656078-kumeu	0/0/3	27.8	<b>108.1</b>	982.6	0.4	9.7/23.0/5.7/55.6
neos-3754480-nidda	3/0/0	<b>2.26e05</b>	0.2	<b>58.3</b>	<b>4.6</b>	-99.8/0.0/13.9/66.2
neos-4300652-rahue	0/0/3	289.9	<b>702.5</b>	704.6	0.4	-8.3/-41.2/-49.7/-25.0
neos-4338804-snowy	0/3/0	<b>14018.6</b>	0.8	95.6	26.4	87.7/0.0/4.9/5.7
neos-4387871-tavua	0/0/3	<b>339.3</b>	<b>26.2</b>	888.7	475.8	55.1/-12.6/-9.7/-10.2
neos-4413714-turia	3/0/0	<b>19.8</b>	<b>31.9</b>	<b>21.0</b>	<b>0.0</b>	54.9/60.1/73.7/100.0
neos-4532248-waihi	0/0/3	949.4	<b>632.9</b>	721.3	63.4	0.0/-22.7/-39.0/-43.1
neos-4647030-tutaki	3/0/0	<b>25.8</b>	<b>23.7</b>	<b>25.4</b>	<b>0.6</b>	-14.7/-26.2/-30.3/-100.0
neos-4722843-widden	0/3/0	<b>23.7</b>	<b>28.0</b>	<b>46.6</b>	<b>5.6</b>	88.0/49.2/49.6/78.1
neos-4738912-atrato	0/3/0	<b>7.4</b>	<b>0.4</b>	<b>18.7</b>	0.0	38.3/-25.0/-33.7/0.0
neos-4763324-toguru	3/0/0	<b>66.3</b>	<b>10.0</b>	<b>5.0</b>	0.0	-10.7/52.6/78.9/0.0
neos-4954672-berkel	3/0/0	<b>81.4</b>	0.1	<b>17.3</b>	<b>0.0</b>	-32.8/0.0/45.9/100.0
neos-5049753-cuanza	0/2/0	73.7	918.2	387.2	81.4	-/-/-/-
neos-5052403-cygnnet	3/0/0	<b>1.0</b>	43.6	2.3	0.0	23.1/-3.4/0.0/0.0
neos-5093327-huahunu	2/1/0	<b>1192.4</b>	<b>19.2</b>	<b>166.9</b>	<b>128.7</b>	-23.4/-30.2/-27.7/-32.7
neos-5104907-jarama	0/0/2	136.7	2268.0	751.4	47.4	-/-/-/-
neos-5107597-kakapo	3/0/0	42996.0	<b>2.2</b>	<b>150.2</b>	<b>122.1</b>	-8.6/-18.2/-17.9/-22.3
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	4235.6	<b>2.1</b>	<b>5.3</b>	0.0	-5.3/63.2/80.1/0.0
neos-5195221-niemur	3/0/0	<b>1012.0</b>	<b>6.5</b>	<b>12.1</b>	0.0	-24.1/12.2/35.3/0.0
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	<b>253.1</b>	<b>4.1</b>	<b>13.2</b>	<b>0.0</b>	-11.9/35.9/31.6/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>4.25e05</b>	<b>45.3</b>	<b>31.6</b>	<b>0.8</b>	-30.4/56.1/54.4/96.1
neos-860300	3/0/0	<b>93.6</b>	<b>0.7</b>	<b>8.0</b>	0.0	-39.1/-42.9/-50.0/0.0
neos-873061	3/0/0	58.5	23.7	31.3	<b>1.3</b>	4.4/7.8/1.3/18.8
neos-911970	3/0/0	<b>152.0</b>	<b>0.1</b>	<b>28.0</b>	<b>0.0</b>	-13.2/50.0/44.0/100.0
neos-933966	3/0/0	<b>306.4</b>	<b>1.2</b>	<b>4.8</b>	0.0	-26.9/25.0/48.9/0.0
neos-950242	3/0/0	<b>144.3</b>	<b>5.1</b>	<b>16.8</b>	<b>0.0</b>	-11.1/23.9/22.9/100.0
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	2/1/0	2.3	<b>14.6</b>	<b>42.5</b>	<b>1.8</b>	0.0/27.7/31.3/14.3
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	1.5	<b>6.6</b>	815.8	5.2	-6.7/29.0/30.2/-50.0
neos17	3/0/0	<b>328.0</b>	0.2	31.7	1.6	-11.5/0.0/0.0/0.0
neos20	0/0/3	<b>61.2</b>	<b>11.6</b>	1377.7	98.4	-25.3/-15.5/-14.2/-17.3
neos5	3/0/0	<b>60.3</b>	0.1	<b>2.9</b>	0.0	-31.0/0.0/23.7/0.0
neos7	0/3/0	<b>13.8</b>	<b>0.1</b>	<b>12.3</b>	0.0	-20.3/50.0/50.8/0.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>24.2</b>	<b>6.9</b>	27.4	<b>0.4</b>	36.8/-37.7/-6.2/-100.0
netdiversion	3/0/0	88.7	<b>64.3</b>	9.0	0.0	-2.6/14.2/6.2/0.0
nexp-150-20-8-5	3/0/0	145.9	<b>0.4</b>	<b>5.0</b>	0.0	0.0/20.0/28.6/0.0
nh97p	0/0/3	10.1	<b>9.1</b>	746.5	159.9	1.0/33.1/31.7/38.3
nh97t	0/1/2	10.8	<b>7.9</b>	736.1	203.4	-1.9/38.3/32.6/37.7
noswot	0/3/0	<b>5.6</b>	0.1	<b>13.0</b>	<b>0.0</b>	41.7/0.0/62.1/100.0
ns1116954	1/1/1	0.0	473.2	467.3	3.2	0.0/-0.3/0.0/0.0
ns1208400	1/2/0	0.0	<b>55.3</b>	<b>221.7</b>	<b>0.0</b>	0.0/38.6/43.9/100.0
ns1644855	3/0/0	<b>18.5</b>	<b>221.0</b>	<b>13.7</b>	<b>0.0</b>	-97.3/43.4/60.3/100.0
ns1760995	3/0/0	15.0	<b>71.6</b>	<b>65.6</b>	<b>0.8</b>	-0.7/15.4/18.5/72.4
ns1830653	3/0/0	<b>315.5</b>	<b>5.2</b>	<b>82.8</b>	<b>1.6</b>	-48.0/-15.4/-29.0/-37.5
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-idx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	<b>4.0</b>	<b>0.1</b>	<b>4.3</b>	0.0	-17.5/66.7/77.4/0.0
nursesched-medium-hint03	0/3/0	812.5	<b>17.8</b>	<b>16.8</b>	0.0	-3.2/-21.9/-32.1/0.0
nursesched-sprint02	0/3/0	58.8	2.1	9.3	0.0	-6.1/-9.5/0.0/0.0
nw04	3/0/0	3.9	<b>1.1</b>	<b>3.6</b>	0.0	0.0/45.0/55.0/0.0
opm2-z10-s4	3/0/0	94.2	27.3	1.0	0.0	0.0/0.0/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	0.1	<b>16.0</b>	<b>0.0</b>	100.0/0.0/55.9/100.0
p200x1188c	3/0/0	3.9	0.2	31.0	1.0	0.0/0.0/0.0/0.0

(continued)

Table A.20 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
p2756	0/3/0	82.1	0.1	<b>4.0</b>	0.0	0.0/0.0/20.0/0.0
peg-solitaire-a3	0/0/1	0.0	303.7	965.0	143.0	-/-/-/-
pg	3/0/0	14.8	<b>0.1</b>	<b>20.0</b>	<b>0.0</b>	4.5/66.7/61.3/100.0
pg5-34	3/0/0	<b>5.2</b>	<b>0.1</b>	<b>17.6</b>	<b>0.0</b>	26.8/75.0/66.2/100.0
physiciansched3-3	2/1/0	<b>175.4</b>	<b>81.4</b>	<b>96.1</b>	<b>5.5</b>	-95.0/-33.0/-52.1/-81.8
physiciansched6-2	0/0/3	<b>1.8</b>	<b>104.0</b>	899.7	51.9	63.3/-18.8/-17.7/-32.9
piperout-08	0/0/3	<b>186.8</b>	<b>42.2</b>	1025.1	39.2	52.7/39.0/40.1/-15.1
piperout-27	0/0/3	<b>464.9</b>	<b>83.1</b>	1491.3	14.7	-50.9/-20.6/-19.7/16.5
pk1	3/0/0	<b>363.0</b>	0.2	<b>46.2</b>	<b>4.0</b>	69.5/0.0/20.3/55.1
pp08a	3/0/0	61.3	0.1	17.0	0.0	-4.7/0.0/-8.2/0.0
pp08aCUTS	3/0/0	<b>26.1</b>	0.1	12.3	0.0	25.6/0.0/-2.4/0.0
proteindesign121hz512p9	0/3/0	2.4	5.0	24.4	0.3	0.0/0.0/0.0/0.0
proteindesign122trx11p8	0/3/0	1.1	1.1	4.0	0.0	0.0/-9.1/0.0/0.0
protfold	3/0/0	<b>55.5</b>	<b>6.3</b>	36.5	0.0	15.9/25.0/3.4/0.0
qap10	3/0/0	19.4	<b>15.6</b>	<b>3.0</b>	0.0	0.0/-12.2/-33.3/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	245.9	<b>0.6</b>	<b>29.2</b>	<b>0.3</b>	-2.3/-16.7/-13.4/-100.0
rB10-011001	3/0/0	223.5	<b>0.6</b>	27.2	<b>0.3</b>	-8.7/-16.7/-3.3/-100.0
rB11-010000	3/0/0	<b>328.2</b>	1.4	30.6	0.6	-12.0/-7.1/-2.0/0.0
rB11-110001	3/0/0	<b>165.1</b>	<b>3.6</b>	<b>29.3</b>	0.3	20.4/-27.8/-20.5/0.0
rB12-111111	0/1/2	83.7	<b>41.0</b>	511.1	3.6	6.9/11.6/11.1/-11.1
rC10-001000	3/0/0	<b>178.2</b>	0.2	27.0	0.0	35.2/0.0/3.2/0.0
rC10-100001	3/0/0	424.9	<b>6.1</b>	<b>127.0</b>	<b>1.2</b>	-3.9/-19.7/-20.1/-33.3
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>464.6</b>	<b>3.7</b>	<b>24.9</b>	<b>0.6</b>	-30.7/27.5/31.6/25.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>229.4</b>	<b>2.2</b>	<b>92.3</b>	<b>12.7</b>	-33.7/-18.2/-26.0/-71.7
radiationm40-10-02	0/3/0	<b>303.1</b>	<b>13.6</b>	<b>115.4</b>	9.3	29.7/16.0/19.7/-3.2
rail01	3/0/0	<b>27.1</b>	1328.2	12.0	0.0	12.6/-3.6/-0.8/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<b>50.5</b>	0.3	23.5	<b>0.8</b>	-67.1/0.0/-3.0/-62.5
rd-rplusc-21	0/0/3	57.3	<b>44.3</b>	1102.0	434.8	1.4/-18.3/-21.4/-17.1
reblock115	3/0/0	<b>12.7</b>	<b>1.9</b>	56.1	6.6	-11.8/-15.8/-1.2/-6.1
rmatr100-p10	3/0/0	31.2	0.6	2.3	0.0	-5.4/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	13.8	2.0	0.0	0.0/2.1/0.0/0.0
rocl-4-11	0/0/3	76.1	19.1	758.2	80.2	-9.1/9.9/18.7/22.7
rocll-5-11	1/2/0	<b>79.2</b>	<b>12.9</b>	<b>233.9</b>	<b>72.0</b>	12.4/-34.9/-33.3/-26.9
roi2alpha3n4	3/0/0	<b>38.0</b>	<b>12.9</b>	<b>14.3</b>	<b>0.0</b>	39.1/61.3/58.3/100.0
roi5alpha10n8	3/0/0	58.7	<b>277.1</b>	<b>18.7</b>	0.0	2.3/38.0/35.5/0.0
roll3000	0/3/0	<b>33.9</b>	1.1	50.9	<b>5.8</b>	-22.7/0.0/-4.9/-22.4
rout	0/3/0	51.2	0.2	<b>39.5</b>	<b>2.6</b>	-3.3/0.0/-10.9/-34.6
s100	3/0/0	<b>24.0</b>	<b>260.0</b>	<b>9.4</b>	0.0	-92.9/14.1/-29.8/0.0
s250r10	3/0/0	<b>1.8</b>	<b>44.6</b>	2.0	0.0	-94.4/16.5/0.0/0.0
satellites2-40	3/0/0	<b>419.9</b>	45.9	34.9	2.7	-41.6/-3.7/0.0/0.0
satellites2-60-fs	3/0/0	<b>128.3</b>	<b>32.9</b>	34.9	2.7	-30.2/-31.3/0.0/0.0
savshed1	0/3/0	<b>12.5</b>	<b>156.8</b>	<b>9.0</b>	0.0	-36.8/17.5/26.8/0.0
sct2	3/0/0	<b>41.2</b>	<b>0.2</b>	<b>7.3</b>	<b>0.0</b>	-29.1/66.7/72.0/100.0
set1ch	3/0/0	<b>65.1</b>	0.1	31.0	1.0	23.9/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	1.4	<b>2.3</b>	<b>5.3</b>	0.0	0.0/14.8/30.3/0.0
sing326	3/0/0	<b>47.9</b>	<b>19.8</b>	<b>24.9</b>	<b>0.6</b>	-77.9/19.8/26.8/62.5
sing44	3/0/0	<b>15.1</b>	<b>12.9</b>	<b>9.4</b>	<b>0.0</b>	-51.0/51.1/75.6/100.0
snp-02-004-104	0/3/0	<b>12.7</b>	19.7	33.0	<b>1.0</b>	-86.6/0.0/1.8/47.4
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.3	1.3	0.0/0.0/0.0/0.0
sp97ar	3/0/0	25.6	<b>0.8</b>	2.2	0.0	3.8/11.1/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	<b>86.4</b>	60.7	14.2	0.0	12.4/2.3/-8.5/0.0
square41	0/3/0	6.7	<b>335.6</b>	<b>5.0</b>	0.0	0.0/72.5/50.0/0.0

(continued)

Table A.20 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
square47	0/2/0	138.2	2259.5	14.4	0.0	-/-/-
supportcase10	3/0/0	<b>31.0</b>	109.6	<b>8.6</b>	0.0	81.8/0.5/36.8/0.0
supportcase12	0/3/0	<b>3.1</b>	<b>11.4</b>	<b>14.2</b>	0.0	-41.9/21.9/32.4/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>11912.6</b>	0.2	89.7	63.3	-21.2/0.0/0.0/0.0
supportcase33	0/3/0	68.7	15.1	<b>149.1</b>	<b>20.3</b>	-6.1/-8.6/-18.6/-28.6
supportcase40	3/0/0	<b>47.9</b>	<b>2.8</b>	<b>12.7</b>	0.0	-63.3/33.3/23.5/0.0
supportcase42	0/3/0	<b>48.4</b>	<b>1.8</b>	<b>3.6</b>	0.0	-49.6/57.1/69.0/0.0
supportcase6	3/0/0	<b>0.3</b>	<b>4.4</b>	<b>3.0</b>	0.0	25.0/66.9/75.0/0.0
supportcase7	3/0/0	<b>27.3</b>	<b>4.6</b>	<b>8.5</b>	0.0	-47.6/44.6/67.3/0.0
swath	1/2/0	182.4	<b>24.4</b>	<b>304.8</b>	<b>96.4</b>	-0.4/-44.7/-38.4/-38.2
swath1	2/1/0	<b>71.7</b>	2.2	61.1	15.2	-15.8/4.3/1.8/3.2
swath3	3/0/0	<b>18.9</b>	<b>2.0</b>	<b>51.6</b>	<b>8.7</b>	43.1/-25.0/-16.9/-63.2
t1717	3/0/0	191.9	128.6	43.8	0.0	-6.6/-1.8/-0.7/0.0
tbfp-network	3/0/0	<b>339.2</b>	<b>12.8</b>	13.6	0.0	-41.2/42.9/2.9/0.0
thor50dday	3/0/0	258.0	7.5	24.5	1.7	-0.1/-4.0/0.0/0.0
timtab1	0/3/0	<b>69.4</b>	<b>0.5</b>	118.6	<b>41.2</b>	-20.0/16.7/-4.1/-32.3
timtab2	0/1/2	<b>64.8</b>	6.1	784.1	275.8	12.0/-4.9/0.9/-1.9
tr12-30	3/0/0	<b>31.9</b>	0.2	32.9	<b>2.5</b>	56.2/0.0/-3.6/-36.0
traininstance2	0/3/0	<b>187.8</b>	<b>3.9</b>	<b>767.0</b>	68.7	22.9/-15.4/-15.3/-0.1
traininstance6	0/2/1	<b>195.8</b>	<b>0.9</b>	220.1	34.0	57.6/25.0/28.0/19.2
trento1	3/0/0	<b>401.5</b>	<b>5.8</b>	<b>4.6</b>	0.0	-53.4/27.5/50.5/0.0
triptim1	0/3/0	0.1	21.7	4.0	0.0	0.0/6.9/0.0/0.0
uccase12	3/0/0	<b>3.6</b>	9.9	15.0	0.0	-47.2/3.9/3.8/0.0
uccase9	2/0/1	<b>520.4</b>	<b>38.8</b>	124.2	34.0	90.7/33.0/34.5/53.4
uct-subprob	3/0/0	<b>17.7</b>	<b>0.7</b>	<b>9.7</b>	0.0	-29.9/-14.3/-20.6/0.0
unitcal-7	0/0/3	<b>37.0</b>	137.8	1000.0	183.2	-27.6/-0.1/-0.8/-20.4
var-smallemerly-m6j6	3/0/0	<b>13.8</b>	<b>15.2</b>	<b>42.7</b>	<b>5.3</b>	94.6/36.7/36.7/47.5
vpm2	3/0/0	44.8	0.1	20.4	0.0	0.4/0.0/0.0/0.0
wachplan	0/3/0	0.0	2.8	<b>33.6</b>	<b>2.7</b>	0.0/6.7/-21.1/-100.0
Geom. means		(271 instances)	(234 instances)			
FP		45.0	5.4	16.6	1.2	
FP+( $\Delta$ )		<b>45.9</b>	<b>4.9</b>	<b>13.7</b>	<b>0.9</b>	

Table A.21.: Performance of FP+( $c, \Delta$ )

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	0/3/0	<b>8.4</b>	<b>14.2</b>	<b>185.0</b>	<b>0.3</b>	30.6/-14.1/-13.7/75.0
30n20b8	0/3/0	<b>221.5</b>	<b>4.5</b>	154.2	28.1	52.1/21.1/7.7/2.8
50v-10	0/3/0	128.0	0.3	<b>20.4</b>	<b>0.0</b>	-2.6/0.0/11.3/100.0
CMS750-4	3/0/0	<b>63.4</b>	<b>3.0</b>	<b>45.8</b>	<b>6.6</b>	-16.4/26.8/29.6/45.0
a1c1s1	3/0/0	<b>90.7</b>	<b>0.5</b>	31.0	<b>1.0</b>	-41.8/-20.0/1.0/23.1
academicmetatablesmall	0/0/3	inf	645.6	1027.2	0.0	-/-/-
aflow30a	3/0/0	<b>165.1</b>	0.1	35.7	<b>3.3</b>	-20.3/0.0/-6.2/-39.4
aflow40b	3/0/0	<b>381.0</b>	0.3	35.3	<b>3.6</b>	-45.6/0.0/-9.3/-58.3
air04	3/0/0	<b>2.3</b>	<b>2.2</b>	7.1	0.0	-95.7/15.4/-7.0/0.0
air05	3/0/0	<b>2.6</b>	0.8	<b>5.0</b>	0.0	36.6/0.0/-20.0/0.0
app1-1	3/0/0	<b>15.6</b>	0.5	33.6	<b>2.5</b>	-80.1/0.0/2.9/37.5
app1-2	3/0/0	43.9	<b>7.1</b>	<b>37.0</b>	<b>6.6</b>	0.0/33.6/28.6/56.9
arki001	0/1/2	3.1	<b>24.8</b>	919.8	198.1	-6.5/-16.5/-12.6/-5.9
assign1-5-8	3/0/0	<b>5.2</b>	0.1	<b>4.3</b>	0.0	-63.5/0.0/80.7/0.0
atlanta-ip	3/0/0	<b>15.1</b>	<b>12.1</b>	<b>11.1</b>	<b>0.0</b>	16.1/28.4/57.0/100.0
b1c1s1	3/0/0	<b>208.5</b>	<b>0.6</b>	33.7	3.6	-22.6/-16.7/0.0/0.0
bab2	1/2/0	<b>53.3</b>	340.6	227.0	67.4	-52.2/-7.8/-23.8/-65.1
bab6	0/3/0	<b>36.1</b>	<b>142.2</b>	<b>168.7</b>	<b>59.8</b>	-34.3/-26.6/-48.0/-74.4
beasleyC3	3/0/0	11.7	0.2	35.0	4.8	-0.9/0.0/0.0/0.0
binkar10-1	3/0/0	<b>2.5</b>	0.1	17.2	0.0	37.5/0.0/-8.7/0.0

(continued)

Table A.21 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
blp-ar98	3/0/0	79.0	2.8	22.9	0.4	-9.7/-28.6/-26.2/-100.0
blp-ic98	3/0/0	37.3	0.4	2.2	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/3	0.0	199.5	717.1	0.0	0.0/6.3/15.4/0.0
bppc4-08	3/0/0	40.3	0.1	5.6	0.0	21.9/91.7/91.0/100.0
brazil3	0/3/0	717.7	63.7	42.3	0.0	-11.6/-66.9/-49.4/0.0
buildingenergy	0/3/0	1.1	119.0	3.0	0.0	0.0/82.9/74.4/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.7	40.3	10.3	0.0/0.0/-0.7/-2.9
chromaticindex1024-7	3/0/0	0.0	60.1	5.0	0.0	0.0/-8.8/-40.0/0.0
chromaticindex512-7	3/0/0	0.0	71.9	5.3	0.0	0.0/-37.4/-62.3/0.0
cmflsp50-24-8-8	0/0/3	18.2	160.1	944.9	283.7	6.7/4.4/10.0/3.7
co-100	3/0/0	274.5	8.7	22.9	0.0	9.3/-29.9/-31.9/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	2930.5	16.1	51.6	1.1	14.5/-61.5/-53.5/-100.0
comp21-2idx	0/3/0	483.3	13.5	60.3	0.8	-11.7/-65.9/-58.4/-100.0
cost266-UUE	3/0/0	37.9	0.4	22.7	0.4	-7.4/0.0/3.4/-25.0
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/2/1	62.3	7.1	558.2	100.3	9.7/-14.1/-31.5/-50.7
csched008	3/0/0	9.2	0.5	51.6	4.2	6.1/70.6/66.1/82.5
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	20.5	2.0	0.0	0.0/-8.8/87.7/0.0
dano3-5	3/0/0	0.3	21.0	2.0	0.0	-33.3/52.3/93.4/100.0
dano3mip	3/0/0	15.4	25.6	5.0	0.0	10.5/90.9/92.9/100.0
danooint	3/0/0	25.6	1.1	46.9	6.3	96.1/72.5/57.9/84.7
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	5.7	0.3	13.3	0.0	-1.8/0.0/-2.3/0.0
drayage-25-23	3/0/0	6.7	0.2	4.0	0.0	34.3/50.0/75.6/0.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0
dws008-01	0/0/3	104.2	95.2	1060.5	304.2	-8.0/-21.6/-22.7/-22.5
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0	0.0/0.0/0.0/0.0
enlight-hard	0/0/0	-	-	-	-	-/-/-/-
exp-1-500-5-5	3/0/0	132.8	0.1	15.5	0.0	-43.2/0.0/42.4/0.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	788.9	0.8	44.6	5.0	13.0/-50.0/-54.5/-100.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	12.5	1.5	8.7	0.0	27.3/78.6/84.5/100.0
fiber	3/0/0	126.5	0.1	14.0	0.0	17.6/0.0/6.0/0.0
fixnet6	3/0/0	59.5	0.1	31.0	1.0	-28.4/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	11.3	0.1	2.9	0.0	-7.1/0.0/0.0/0.0
germanrr	0/3/0	4.9	11.6	56.4	7.1	-16.3/0.9/-9.9/-16.9
gesa2	0/3/0	2.6	0.2	20.4	0.0	-7.7/0.0/0.0/0.0
gesa2-o	0/3/0	18.0	0.2	36.5	1.5	10.0/0.0/-2.5/0.0
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	3/0/0	185.5	0.1	48.2	10.9	72.8/66.7/53.7/66.1
gmu-35-40	3/0/0	7.4	0.1	3.0	0.0	-12.2/0.0/78.6/0.0
gmu-35-50	3/0/0	18.9	0.3	27.0	0.6	-35.4/0.0/14.0/40.0
graph20-20-1rand	3/0/0	22.2	2.3	17.9	0.0	-36.9/43.9/42.8/100.0
graphdraw-domain	0/3/0	163.5	0.3	50.1	10.4	-82.4/0.0/17.5/0.0
h80x6320d	3/0/0	22.9	1.2	32.0	1.9	-3.9/0.0/0.0/0.0
harp2	3/0/0	12.8	0.1	17.9	0.0	-3.1/0.0/-29.1/0.0
highschool1-aigio	0/3/0	inf	1467.5	51.9	0.3	0.0/-53.1/-70.5/-100.0
hypothyroid-k1	3/0/0	0.0	4.7	1.0	0.0	0.0/2.1/0.0/0.0
ic97p	0/0/3	16.8	3.6	637.8	144.9	-8.3/29.4/28.1/29.5
ic97t	0/0/3	12.7	3.1	974.5	249.5	-2.4/20.5/23.0/19.8
icir97p	0/0/3	20.1	18.2	988.7	151.5	12.2/15.7/13.3/29.8
icir97t	0/3/0	13.1	2.8	135.8	71.1	16.6/36.4/35.5/44.8
irish-electricity	3/0/0	7.4	10.8	5.6	0.0	-18.9/44.3/76.9/100.0
irp	3/0/0	3.9	0.3	2.8	0.0	-2.6/0.0/17.6/0.0

(continued)

Table A.21 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
istanbul-no-cutoff	3/0/0	36.0	<b>4.5</b>	<b>12.6</b>	0.0	0.0/29.7/42.7/0.0
k1mushroom	3/0/0	18.2	40.2	1.0	0.0	0.0/-1.0/0.0/0.0
lectsched-5-obj	0/0/3	<b>2803.5</b>	<b>119.7</b>	1301.1	14.3	-19.9/-29.8/-30.2/-51.0
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>407.2</b>	<b>0.2</b>	<b>13.3</b>	<b>0.0</b>	39.6/81.8/85.2/100.0
lotsize	3/0/0	<b>273.3</b>	0.5	44.0	9.6	-74.1/0.0/2.0/8.6
mad	3/0/0	<b>9693.2</b>	0.1	15.3	0.0	21.6/0.0/-3.9/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>66.2</b>	<b>14.6</b>	<b>8.0</b>	<b>0.0</b>	-32.5/70.7/77.7/100.0
map16715-04	3/0/0	85.0	<b>21.3</b>	<b>8.7</b>	<b>0.0</b>	4.7/62.6/81.2/100.0
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>41.6</b>	<b>0.1</b>	<b>7.2</b>	<b>0.0</b>	91.3/50.0/92.0/100.0
mas76	0/3/0	<b>14.0</b>	<b>0.1</b>	<b>4.6</b>	<b>0.0</b>	86.8/50.0/94.9/100.0
mc11	3/0/0	117.5	0.4	43.0	13.0	-7.9/0.0/-0.9/-5.4
mcsched	3/0/0	<b>7.2</b>	0.5	<b>4.3</b>	0.0	44.2/0.0/-16.3/0.0
mik-250-20-75-4	0/3/0	<b>2.2</b>	<b>0.1</b>	<b>6.3</b>	<b>0.0</b>	96.4/50.0/83.6/100.0
milo-v12-6-r2-40-1	3/0/0	145.6	0.9	42.0	11.9	3.1/0.0/0.0/0.8
misc07	3/0/0	31.3	0.1	<b>17.0</b>	0.0	-8.6/0.0/15.4/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>12.0</b>	<b>0.1</b>	<b>4.9</b>	0.0	14.3/66.7/75.0/0.0
modglob	3/0/0	<b>50.8</b>	0.1	<b>5.6</b>	<b>0.0</b>	52.0/0.0/82.1/100.0
momentum1	0/3/0	<b>139.4</b>	<b>22.6</b>	<b>301.9</b>	<b>168.0</b>	27.9/42.8/45.9/52.4
msc98-ip	3/0/0	<b>20.9</b>	<b>5.5</b>	29.1	0.6	-25.8/12.7/5.2/0.0
mushroom-best	0/3/0	<b>6.37e06</b>	<b>18.0</b>	<b>52.6</b>	<b>1.4</b>	30.5/-24.4/-24.0/17.6
mzzv11	0/3/0	<b>22.6</b>	<b>2.9</b>	<b>13.6</b>	0.0	-11.1/31.0/29.5/0.0
mzzv42z	0/3/0	<b>24.5</b>	<b>2.1</b>	<b>7.0</b>	<b>0.0</b>	21.0/57.1/70.6/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>6.6</b>	0.3	20.4	0.0	29.8/0.0/0.0/0.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>17.1</b>	<b>1.3</b>	<b>4.3</b>	<b>0.0</b>	-94.7/73.5/83.7/100.0
neos-1171737	3/0/0	<b>12.1</b>	<b>0.4</b>	<b>3.6</b>	<b>0.0</b>	-67.8/75.0/87.8/100.0
neos-1354092	0/3/0	18.8	<b>128.9</b>	<b>28.6</b>	0.0	-3.7/26.9/23.9/0.0
neos-1445765	3/0/0	<b>25.1</b>	<b>0.7</b>	<b>5.0</b>	0.0	29.1/12.5/10.7/0.0
neos-1456979	0/2/1	147.6	<b>72.2</b>	817.8	142.7	1.5/-44.0/-43.5/-32.4
neos-1582420	0/3/0	<b>77.1</b>	<b>1.3</b>	<b>64.1</b>	<b>3.7</b>	-10.5/13.3/19.4/60.6
neos-2657525-crna	0/2/1	<b>1310.6</b>	<b>0.7</b>	106.6	3.5	-22.4/-71.4/-60.8/-42.9
neos-2746589-doon	0/1/2	35.8	<b>420.4</b>	396.5	29.2	-2.5/-67.2/-37.4/6.7
neos-2978193-inde	3/0/0	3.3	0.2	<b>3.6</b>	0.0	0.0/0.0/-36.1/0.0
neos-2987310-joes	2/1/0	0.3	<b>10.6</b>	54.3	14.8	0.0/-10.4/0.0/0.0
neos-3004026-krka	0/0/3	0.0	108.8	1285.7	3.6	0.0/0.2/0.0/0.0
neos-3024952-loue	0/0/3	772.7	75.4	1295.9	15.3	5.0/5.6/8.4/45.0
neos-3046615-murg	0/3/0	<b>809.8</b>	0.2	93.0	64.3	92.6/0.0/1.4/2.0
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	<b>134.4</b>	<b>408.9</b>	954.9	1.0	-10.0/10.8/12.9/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>15.8</b>	931.3	0.3	0.0/13.7/11.6/72.7
neos-3402294-bobin	3/0/0	<b>238.5</b>	<b>23.6</b>	17.4	0.0	44.4/-14.8/8.9/0.0
neos-3555904-turama	1/2/0	<b>4.4</b>	<b>139.8</b>	<b>79.7</b>	<b>3.0</b>	-54.5/-44.1/-60.6/-86.7
neos-3627168-kasai	3/0/0	1.5	0.1	22.0	<b>0.3</b>	0.0/0.0/-7.3/-100.0
neos-3656078-kumeu	0/0/3	<b>24.4</b>	130.7	1344.8	14.9	20.8/6.8/-22.6/-94.0
neos-3754480-nidda	3/0/0	<b>2.27e05</b>	<b>0.1</b>	<b>10.3</b>	<b>0.0</b>	-99.8/50.0/84.8/100.0
neos-4300652-rahue	0/0/3	256.3	<b>638.9</b>	737.1	0.8	3.6/-35.4/-51.9/-62.5
neos-4338804-snowy	0/3/0	<b>375.6</b>	<b>0.6</b>	<b>68.6</b>	<b>19.6</b>	99.7/25.0/31.7/30.0
neos-4387871-tavua	0/0/3	793.5	24.6	841.3	435.6	-4.9/-6.9/-4.7/-1.9
neos-4413714-turia	3/0/0	<b>87.1</b>	<b>18.5</b>	<b>7.0</b>	<b>0.0</b>	-49.6/76.8/91.2/100.0
neos-4532248-waihi	0/0/3	949.4	<b>548.4</b>	732.6	70.4	0.0/-10.8/-40.0/-48.7
neos-4647030-tutaki	3/0/0	<b>97.0</b>	<b>13.3</b>	<b>13.0</b>	0.0	-77.3/24.0/26.6/0.0
neos-4722843-widden	0/3/0	<b>94.1</b>	<b>26.2</b>	<b>46.3</b>	<b>4.8</b>	52.4/52.5/49.9/81.2

(continued)

Table A.21 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-4738912-atrato	0/3/0	10.8	0.3	14.3	0.0	10.0/0.0/-13.3/0.0
neos-4763324-toguru	3/0/0	51.5	14.6	9.3	0.0	13.0/30.8/60.8/0.0
neos-4954672-berkel	3/0/0	44.3	0.1	11.5	0.0	19.0/0.0/64.1/100.0
neos-5049753-cuanza	0/2/0	80.7	980.1	381.5	113.9	-/-/-/-
neos-5052403-cygnnet	3/0/0	0.7	42.1	2.3	0.0	46.2/0.0/0.0/0.0
neos-5093327-huahum	2/1/0	1178.6	15.7	129.0	93.2	-22.5/-14.6/-6.4/-7.1
neos-5104907-jarama	0/0/0	-	-	-	-	-/-/-/-
neos-5107597-kakapo	3/0/0	43133.4	1.8	123.5	94.9	-8.9/0.0/-0.2/0.0
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	4344.6	4.0	14.2	0.0	-7.6/29.8/46.8/0.0
neos-5195221-niemur	3/0/0	962.4	7.9	13.7	0.0	-20.2/-6.3/26.7/0.0
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	259.4	4.0	11.3	0.0	-14.0/37.5/41.5/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	2.27e05	105.1	70.7	20.6	23.3/-1.7/-2.0/0.5
neos-860300	3/0/0	6.7	0.7	8.0	0.0	88.2/-42.9/-50.0/0.0
neos-873061	3/0/0	57.9	24.2	31.3	1.3	5.4/5.8/1.3/18.8
neos-911970	3/0/0	231.7	0.1	18.0	0.0	-43.0/50.0/64.0/100.0
neos-933966	3/0/0	11.6	4.7	10.1	0.0	94.8/-66.0/-6.9/0.0
neos-950242	3/0/0	61.9	8.9	26.3	0.3	51.8/-24.7/-17.1/25.0
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	3/0/0	2.4	9.2	29.9	0.0	-4.2/54.5/51.7/100.0
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	2.0	8.3	1023.4	3.3	-30.0/10.8/12.4/-21.2
neos17	3/0/0	329.5	0.2	34.9	2.7	-11.9/0.0/-9.2/-40.7
neos20	0/0/3	70.3	7.7	879.2	50.2	-35.0/21.4/25.6/38.3
neos5	3/0/0	24.4	0.1	2.7	0.0	41.3/0.0/28.9/0.0
neos7	0/3/0	13.0	0.1	5.1	0.0	-15.4/50.0/79.6/0.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	30.5	4.4	20.9	0.0	20.4/-2.3/18.7/0.0
netdiversion	3/0/0	80.5	179.7	13.5	0.0	6.8/-58.3/-28.9/0.0
nexp-150-20-8-5	3/0/0	145.9	0.3	3.0	0.0	0.0/40.0/57.1/0.0
nh97p	0/0/3	10.2	13.3	1087.8	253.4	0.0/2.2/0.4/2.2
nh97t	0/0/3	10.4	16.9	1424.2	377.1	1.9/-24.3/-23.3/-13.4
noswot	0/3/0	0.5	0.1	10.1	0.6	94.8/0.0/70.6/53.8
ns1116954	1/1/1	0.0	473.3	467.3	3.2	0.0/-0.3/0.0/0.0
ns1208400	1/2/0	0.0	81.3	319.5	0.6	0.0/9.8/19.2/-50.0
ns1644855	3/0/0	21.6	191.7	4.6	0.0	-97.7/50.9/86.7/100.0
ns1760995	3/0/0	27.2	13.1	9.6	0.0	-45.2/84.5/88.1/100.0
ns1830653	1/2/0	287.8	13.2	237.6	3.8	-42.9/-66.7/-75.3/-73.7
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-1px	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.3	0.1	3.0	0.0	0.0/66.7/84.2/0.0
nursesched-medium-hint03	0/3/0	678.2	81.1	33.6	0.3	13.8/-82.9/-66.1/-100.0
nursesched-sprint02	0/3/0	43.0	2.7	12.3	0.0	22.1/-29.6/-24.4/0.0
nw04	3/0/0	3.9	1.2	4.3	0.0	0.0/40.0/46.2/0.0
opm2-z10-s4	3/0/0	94.2	27.3	1.0	0.0	0.0/0.0/0.0/0.0
opt1217	3/0/0	0.0	0.1	4.0	0.0	100.0/0.0/89.0/100.0
p200x1188c	3/0/0	3.9	0.2	31.0	1.0	0.0/0.0/0.0/0.0
p2756	0/3/0	78.1	0.1	5.0	0.0	4.9/0.0/0.0/0.0
peg-solitaire-a3	0/0/2	0.0	683.5	907.2	38.1	-/-/-/-
pg	3/0/0	18.9	0.1	9.7	0.0	-18.0/66.7/81.2/100.0
pg5-34	3/0/0	6.3	0.1	6.8	0.0	11.3/75.0/86.9/100.0
physiciansched3-3	3/0/0	266.9	48.8	98.4	5.8	-96.7/10.5/-53.3/-82.8
physiciansched6-2	0/0/3	4.4	96.0	836.8	44.5	10.2/-12.1/-11.5/-21.8
piperout-08	0/0/3	298.5	47.8	1170.2	19.5	24.4/30.9/31.6/41.4
piperout-27	0/0/3	468.2	61.4	1139.2	15.7	-51.2/7.0/4.8/10.8
pk1	3/0/0	523.7	0.1	29.4	0.3	56.1/50.0/49.3/96.6
pp08a	3/0/0	88.4	0.1	17.7	0.0	-33.9/0.0/-11.9/0.0
pp08aCUTS	3/0/0	64.5	0.1	15.1	0.0	-45.6/0.0/-20.5/0.0

(continued)



Table A.21 continued

problem	stage	1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
proteindesign121hz512p9	0/1/2		<b>25.8</b>	<b>182.3</b>	780.6	17.7	-90.7/-97.3/-96.9/-98.3
proteindesign122trx11p8	0/1/2		<b>1.4</b>	<b>47.9</b>	213.7	5.0	-21.4/-97.9/-98.1/-100.0
protfold	3/0/0		<b>58.0</b>	<b>3.9</b>	<b>17.8</b>	0.0	12.1/53.6/52.9/0.0
qap10	3/0/0		<b>14.7</b>	<b>18.7</b>	<b>4.0</b>	0.0	24.2/-26.7/-50.0/0.0
qiu	3/0/0	1563.9		0.1	<b>3.8</b>	0.0	0.0/0.0/-13.2/0.0
rB10-011000	3/0/0	264.5		0.5	27.5	<b>0.3</b>	-9.2/0.0/-8.0/-100.0
rB10-011001	3/0/0	218.6		0.5	27.2	<b>0.3</b>	-6.6/0.0/-3.3/-100.0
rB11-010000	3/0/0	286.1		1.3	29.0	<b>0.3</b>	0.9/0.0/3.3/50.0
rB11-110001	3/0/0	<b>174.5</b>		<b>3.0</b>	<b>26.1</b>	0.3	15.9/-13.3/-10.7/0.0
rB12-111111	0/0/3	85.8		<b>90.1</b>	1139.9	7.1	4.6/-48.5/-49.6/-54.9
rC10-001000	3/0/0	<b>144.8</b>		0.2	26.5	0.0	47.4/0.0/5.0/0.0
rC10-100001	2/1/0	<b>521.2</b>		<b>5.5</b>	112.4	<b>3.5</b>	-21.6/-10.9/-9.7/-77.1
rC11-010100	3/0/0	347.0		0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5		0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>561.7</b>		4.7	<b>31.4</b>	<b>1.1</b>	-42.7/7.8/13.7/-27.3
rC12-111100	3/0/0	194.9		0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>197.6</b>		<b>2.3</b>	<b>92.6</b>	<b>10.5</b>	-23.0/-21.7/-26.2/-65.7
radiationm40-10-02	0/3/0	<b>133.9</b>		16.4	<b>165.1</b>	<b>17.6</b>	68.9/-1.2/-12.9/-48.9
rail01	2/1/0	<b>39.0</b>		<b>2153.7</b>	<b>27.5</b>	0.0	-20.5/-40.6/-56.7/0.0
rail02	0/0/0	-		-	-	-	-/-/-/-
rail507	3/0/0	23.3		1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<b>24.8</b>		0.3	23.3	<b>0.6</b>	-33.1/0.0/-2.1/-50.0
rd-rplusc-21	0/0/3	56.1		36.0	854.8	344.4	3.4/0.6/1.4/4.5
reblock115	3/0/0	12.1		<b>0.7</b>	<b>21.8</b>	<b>0.3</b>	-7.4/56.3/60.6/95.2
rmatr100-p10	3/0/0	<b>2.2</b>		<b>0.9</b>	<b>4.3</b>	0.0	92.5/-33.3/-46.5/0.0
rmatr200-p5	3/0/0	19.9		<b>31.5</b>	<b>6.0</b>	0.0	-2.0/-55.2/-66.7/0.0
rocl-4-11	0/0/3	<b>55.0</b>		<b>24.5</b>	1050.2	103.7	20.5/-13.5/-11.2/0.1
rocll-5-11	1/2/0	90.4		<b>15.2</b>	<b>272.2</b>	<b>89.6</b>	0.0/-44.7/-42.7/-41.3
roi2alpha3n4	3/0/0	<b>51.5</b>		<b>7.2</b>	<b>7.0</b>	<b>0.0</b>	17.5/78.4/79.6/100.0
roi5alpha10n8	3/0/0	56.6		<b>84.8</b>	<b>7.0</b>	0.0	5.8/81.0/75.9/0.0
roll3000	0/3/0	<b>37.5</b>		<b>0.8</b>	<b>42.3</b>	<b>3.6</b>	-30.1/27.3/12.6/20.0
rout	0/3/0	<b>56.8</b>		0.2	<b>46.2</b>	<b>5.2</b>	-12.9/0.0/-23.8/-67.3
s100	3/0/0	<b>3.0</b>		275.4	<b>5.0</b>	0.0	-43.3/9.0/24.2/0.0
s250r10	3/0/0	0.1		51.1	2.0	0.0	0.0/4.3/0.0/0.0
satellites2-40	3/0/0	231.4		<b>260.5</b>	37.9	<b>1.2</b>	5.7/-83.0/-7.9/55.6
satellites2-60-fs	3/0/0	<b>169.2</b>		<b>194.9</b>	35.2	2.7	-47.1/-88.4/-0.9/0.0
savshed1	0/3/0	<b>17.2</b>		<b>142.7</b>	<b>7.7</b>	0.0	-54.1/24.9/37.4/0.0
sct2	3/0/0	<b>37.1</b>		<b>0.2</b>	<b>5.3</b>	<b>0.0</b>	-21.3/66.7/79.7/100.0
set1ch	3/0/0	90.9		0.1	31.0	1.0	-5.8/0.0/0.0/0.0
seymour	3/0/0	12.7		0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<b>3.2</b>		<b>1.6</b>	<b>3.0</b>	0.0	-56.3/40.7/60.5/0.0
sing326	3/0/0	<b>67.1</b>		<b>12.3</b>	<b>8.1</b>	<b>0.0</b>	-84.2/50.2/76.2/100.0
sing44	3/0/0	<b>17.6</b>		<b>10.0</b>	<b>3.6</b>	<b>0.0</b>	-58.0/62.1/90.6/100.0
snp-02-004-104	0/3/0	<b>1567.0</b>		<b>22.0</b>	33.0	<b>1.0</b>	-99.9/-10.5/1.8/47.4
sorrell3	3/0/0	76.3		0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9		0.1	31.3	1.3	0.0/0.0/0.0/0.0
sp97ar	3/0/0	26.7		0.9	2.2	0.0	-0.4/0.0/0.0/0.0
sp98ar	3/0/0	24.1		0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.0		<b>55.7</b>	<b>9.0</b>	0.0	-0.4/10.3/30.8/0.0
square41	0/3/0	6.7		<b>1395.7</b>	11.0	0.0	0.0/-12.5/-9.1/0.0
square47	0/0/0	-		-	-	-	-/-/-/-
supportcase10	3/0/0	<b>28.6</b>		102.2	<b>8.6</b>	0.0	83.2/7.2/36.8/0.0
supportcase12	0/3/0	<b>4.9</b>		<b>4.3</b>	<b>3.9</b>	0.0	-63.3/70.5/81.4/0.0
supportcase18	3/0/0	37.5		0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>56.7</b>		0.2	<b>76.0</b>	<b>45.6</b>	99.4/0.0/15.3/28.0
supportcase33	0/3/0	<b>76.5</b>		<b>17.1</b>	<b>163.7</b>	<b>44.4</b>	-15.7/-19.3/-25.9/-67.3
supportcase40	3/0/0	<b>131.1</b>		<b>1.7</b>	<b>7.7</b>	0.0	-86.6/59.5/53.6/0.0
supportcase42	0/3/0	<b>18.0</b>		<b>2.4</b>	<b>5.3</b>	0.0	26.2/42.9/54.3/0.0
supportcase6	3/0/0	<b>0.5</b>		<b>4.6</b>	<b>4.0</b>	0.0	-20.0/65.4/66.7/0.0
supportcase7	3/0/0	<b>19.3</b>		<b>5.0</b>	<b>8.9</b>	0.0	-25.9/39.8/65.8/0.0
swath	0/2/1	192.8		<b>42.0</b>	447.8	142.5	-5.8/-67.9/-58.1/-58.2

(continued)

Table A.21 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
swath1	3/0/0	<b>28.2</b>	<b>2.0</b>	58.5	14.3	53.3/13.0/5.9/8.9
swath3	3/0/0	<b>14.6</b>	<b>1.9</b>	<b>55.0</b>	<b>13.0</b>	56.0/-21.1/-22.0/-75.4
t1717	3/0/0	172.4	<b>100.4</b>	<b>33.2</b>	0.0	3.8/20.5/23.7/0.0
tbfp-network	3/0/0	<b>26.5</b>	<b>16.5</b>	<b>12.2</b>	0.0	86.7/26.3/12.9/0.0
thor50dday	3/0/0	<b>303.3</b>	7.6	25.3	<b>1.9</b>	-15.0/-5.3/-3.2/-10.5
timtab1	0/3/0	53.3	<b>0.4</b>	<b>98.0</b>	28.9	4.0/33.3/13.8/-3.5
timtab2	0/1/2	68.7	<b>4.9</b>	641.3	210.5	6.7/15.5/19.0/22.2
tr12-30	3/0/0	<b>55.2</b>	<b>0.1</b>	30.2	<b>1.2</b>	24.3/50.0/4.7/25.0
traininstance2	0/3/0	<b>567.3</b>	<b>2.7</b>	<b>532.5</b>	<b>59.0</b>	-57.1/18.2/18.0/14.0
traininstance6	0/2/1	<b>195.8</b>	<b>0.9</b>	220.1	34.0	57.6/25.0/28.0/19.2
trento1	3/0/0	<b>47.0</b>	<b>14.3</b>	<b>12.8</b>	0.0	74.9/-44.1/-27.3/0.0
triptim1	0/3/0	0.1	21.7	4.0	0.0	0.0/6.9/0.0/0.0
uccase12	3/0/0	<b>3.5</b>	9.8	14.6	0.0	-45.7/4.9/6.4/0.0
uccase9	3/0/0	<b>322.6</b>	<b>10.7</b>	25.6	2.2	94.2/81.5/86.5/97.0
uct-subprob	3/0/0	<b>19.6</b>	<b>0.5</b>	<b>6.7</b>	0.0	-36.7/16.7/13.0/0.0
unitcal-7	0/0/3	<b>32.1</b>	135.7	993.8	150.0	-16.5/1.5/-0.2/-2.7
var-smallemary-m6j6	3/0/0	<b>22.5</b>	<b>2.9</b>	<b>5.3</b>	<b>0.0</b>	91.2/87.9/92.1/100.0
vpm2	3/0/0	46.1	0.1	20.4	0.0	-2.4/0.0/0.0/0.0
wachplan	0/3/0	0.0	<b>1.6</b>	<b>17.0</b>	0.0	0.0/46.7/35.8/0.0
Geom. means		(271 instances)	(232 instances)			
FP		45.0	5.4	16.8	1.3	
FP+(c, $\Delta$ )		<b>43.7</b>	<b>5.1</b>	<b>12.0</b>	<b>0.8</b>	

Table A.22.: Performance of FP+(3,1,g,c, $\Delta$ )

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	1/2/0	<b>9.9</b>	<b>9.1</b>	163.2	<b>3.7</b>	18.2/25.4/-2.2/-67.6
30n20b8	0/2/1	<b>548.8</b>	<b>9.1</b>	325.9	84.6	-15.8/-37.4/-48.8/-65.8
50v-10	0/3/0	136.9	<b>0.2</b>	<b>18.4</b>	<b>0.0</b>	-8.9/33.3/20.0/100.0
CMS750-4	3/0/0	<b>76.9</b>	<b>5.3</b>	<b>88.7</b>	<b>13.7</b>	-31.1/-22.6/-26.6/-12.4
a1c1s1	3/0/0	<b>31.9</b>	<b>0.7</b>	31.3	1.3	39.6/-42.9/0.0/0.0
academictimetables	0/0/3	inf	662.3	1223.4	0.3	-/-/-/-
aflow30a	3/0/0	<b>162.9</b>	0.1	34.8	<b>2.6</b>	-19.2/0.0/-3.7/-23.1
aflow40b	3/0/0	<b>367.3</b>	<b>0.4</b>	<b>37.3</b>	<b>4.3</b>	-43.6/-25.0/-14.2/-65.1
air04	3/0/0	<b>3.9</b>	<b>3.2</b>	<b>22.1</b>	<b>0.3</b>	-97.4/-18.8/-70.1/-100.0
air05	3/0/0	<b>2.4</b>	<b>0.9</b>	<b>5.0</b>	0.0	41.5/-11.1/-20.0/0.0
app1-1	3/0/0	<b>53.0</b>	<b>0.6</b>	35.9	3.8	-94.2/-16.7/-3.6/5.0
app1-2	3/0/0	43.9	<b>7.4</b>	<b>37.9</b>	<b>6.9</b>	0.0/30.8/26.8/54.9
arki001	0/1/2	3.1	<b>26.6</b>	958.2	226.0	-6.5/-22.2/-16.1/-17.5
assign1-5-8	3/0/0	<b>5.3</b>	0.1	<b>5.6</b>	0.0	-64.2/0.0/74.9/0.0
atlanta-ip	3/0/0	<b>14.9</b>	<b>15.2</b>	24.4	<b>0.3</b>	17.2/10.1/5.4/50.0
b1c1s1	3/0/0	<b>102.2</b>	<b>0.7</b>	34.7	<b>4.3</b>	36.6/-28.6/-2.9/-16.3
bab2	0/1/2	<b>22.7</b>	<b>907.5</b>	765.2	261.3	11.0/-65.4/-77.4/-91.0
bab6	3/0/0	<b>16.2</b>	<b>74.9</b>	<b>75.8</b>	<b>2.3</b>	31.6/28.3/13.6/85.0
beasleyC3	3/0/0	10.6	0.2	35.7	<b>5.6</b>	8.6/0.0/-2.0/-14.3
binkar10-1	3/0/0	<b>1.7</b>	0.1	14.3	0.0	57.5/0.0/8.9/0.0
blp-ar98	3/0/0	71.4	1.8	<b>14.5</b>	0.0	-0.1/10.0/14.2/0.0
blp-ic98	3/0/0	36.3	0.4	2.2	0.0	2.7/0.0/0.0/0.0
bnatt400	0/0/0	-	-	-	-	-/-/-/-
bppc4-08	3/0/0	<b>57.6</b>	<b>0.1</b>	<b>6.2</b>	<b>0.0</b>	-10.4/91.7/90.0/100.0
brazil3	0/3/0	<b>489.8</b>	<b>42.4</b>	<b>48.6</b>	0.0	22.8/-50.2/-56.0/0.0
buildingenergy	0/3/0	<b>0.9</b>	<b>167.0</b>	<b>4.0</b>	0.0	18.2/76.0/65.8/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.7	40.3	10.3	0.0/0.0/-0.7/-2.9
chromaticindex1024-7	3/0/0	0.0	60.5	<b>6.3</b>	0.0	0.0/-9.4/-52.4/0.0
chromaticindex512-7	3/0/0	0.0	<b>75.7</b>	<b>6.3</b>	0.0	0.0/-40.6/-68.3/0.0
cmflsp50-24-8-8	2/1/0	<b>15.0</b>	<b>14.3</b>	107.4	24.9	23.1/91.5/89.8/91.5

(continued)

Table A.22 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
co-100	3/0/0	<b>337.0</b>	<b>7.5</b>	<b>19.0</b>	0.0	-10.1/-18.7/-17.9/0.0
cod105	3/0/0	100.0	1.7	1.0	0.0	0.0/5.6/0.0/0.0
comp07-2idx	0/3/0	<b>2840.4</b>	<b>17.0</b>	<b>60.3</b>	<b>0.3</b>	17.1/-63.5/-60.2/-100.0
comp21-2idx	0/3/0	406.2	<b>14.5</b>	<b>63.3</b>	<b>1.3</b>	4.8/-68.3/-60.3/-100.0
cost266-UUE	3/0/0	36.9	0.4	24.3	<b>0.8</b>	-4.9/0.0/-3.3/-62.5
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/1/2	71.0	<b>9.8</b>	922.2	234.4	-2.8/-37.8/-58.5/-78.9
csched008	1/2/0	9.6	1.6	136.9	23.0	2.0/5.9/9.9/4.2
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	19.6	<b>2.0</b>	0.0	0.0/-4.6/87.7/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>21.0</b>	<b>2.0</b>	<b>0.0</b>	-33.3/52.3/93.4/100.0
dano3mip	3/0/0	<b>15.4</b>	<b>25.9</b>	<b>5.0</b>	<b>0.0</b>	10.5/90.8/92.9/100.0
danooint	2/1/0	<b>43.8</b>	<b>1.4</b>	<b>70.5</b>	<b>13.0</b>	93.3/65.0/36.8/68.4
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>17.8</b>	<b>0.5</b>	<b>18.4</b>	0.0	-68.5/-40.0/-29.3/0.0
drayage-25-23	3/0/0	<b>6.7</b>	<b>0.2</b>	<b>5.0</b>	0.0	34.3/50.0/69.5/0.0
ds	3/0/0	4945.0	6.0	1.0	0.0	0.0/0.0/0.0/0.0
dws008-01	0/0/3	<b>59.5</b>	74.3	848.8	257.1	38.0/0.4/-3.4/-8.3
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0	0.0/0.0/0.0/0.0
enlight-hard	0/0/2	0.0	3.6	777.5	253.8	-/-/-/-
exp-1-500-5-5	3/0/0	<b>229.9</b>	0.1	24.9	<b>0.3</b>	-67.2/0.0/7.4/-100.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>1021.7</b>	<b>0.7</b>	<b>41.3</b>	<b>2.3</b>	-11.2/-42.9/-50.8/-100.0
fhnw-binpack4-48	0/0/2	0.0	74.8	1798.8	226.3	-/-/-/-
fiball	0/3/0	<b>13.8</b>	<b>1.6</b>	<b>9.0</b>	<b>0.0</b>	19.8/77.1/83.9/100.0
fiber	3/0/0	<b>126.5</b>	0.1	14.0	0.0	17.6/0.0/6.0/0.0
fixnet6	3/0/0	<b>54.7</b>	0.1	31.0	1.0	-22.1/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	11.3	0.1	2.9	0.0	-7.1/0.0/0.0/0.0
germanrr	0/3/0	4.3	<b>9.2</b>	54.4	5.8	-4.7/21.4/-6.6/1.7
gesa2	0/3/0	2.6	0.2	20.4	0.0	-7.7/0.0/0.0/0.0
gesa2-o	0/3/0	<b>17.4</b>	0.2	34.8	<b>1.3</b>	13.0/0.0/2.2/13.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	<b>0.5</b>	1.0	0.0	0.0/16.7/0.0/0.0
glass4	3/0/0	<b>382.1</b>	0.3	<b>90.0</b>	33.7	43.9/0.0/13.6/-4.5
gmu-35-40	3/0/0	<b>7.4</b>	0.1	<b>3.0</b>	0.0	-12.2/0.0/78.6/0.0
gmu-35-50	3/0/0	<b>15.2</b>	0.3	<b>18.8</b>	1.0	-19.7/0.0/40.1/0.0
graph20-20-1rand	3/0/0	<b>25.5</b>	<b>2.8</b>	<b>26.8</b>	<b>0.0</b>	-45.1/31.7/14.4/100.0
graphdraw-domain	0/3/0	<b>71.1</b>	<b>0.2</b>	<b>27.4</b>	<b>2.8</b>	-59.5/33.3/54.9/73.1
h80x6320d	3/0/0	22.5	1.2	32.0	1.9	-2.2/0.0/0.0/0.0
harp2	3/0/0	11.6	0.1	13.0	0.0	6.5/0.0/-2.3/0.0
highschool1-aigio	0/3/0	inf	<b>1209.8</b>	<b>54.7</b>	0.0	0.0/-43.1/-72.0/0.0
hypothyroid-k1	3/0/0	0.0	4.8	1.0	0.0	0.0/0.0/0.0/0.0
ic97p	0/0/3	14.5	<b>6.6</b>	1033.1	313.4	5.8/-22.7/-14.2/-34.5
ic97t	0/0/3	12.7	<b>3.5</b>	1104.3	317.4	-2.4/10.3/12.8/-2.0
icir97p	0/0/3	20.8	<b>18.3</b>	780.1	166.5	9.2/15.3/31.6/22.8
icir97t	0/3/0	<b>14.1</b>	4.3	<b>155.1</b>	<b>80.1</b>	10.2/2.3/26.3/37.8
irish-electricity	3/0/0	<b>7.5</b>	<b>10.3</b>	<b>7.0</b>	<b>0.0</b>	-20.0/46.9/71.1/100.0
irp	3/0/0	<b>2.5</b>	0.3	<b>2.8</b>	0.0	34.2/0.0/17.6/0.0
istanbul-no-cutoff	3/0/0	<b>22.1</b>	<b>4.6</b>	<b>13.6</b>	0.0	38.6/28.1/38.2/0.0
k1mushroom	3/0/0	18.2	39.7	1.0	0.0	0.0/0.3/0.0/0.0
lectsched-5-obj	0/0/3	<b>2562.8</b>	<b>96.7</b>	991.0	6.8	-12.4/-13.1/-8.3/2.9
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>407.2</b>	<b>0.2</b>	<b>13.6</b>	<b>0.0</b>	39.6/81.8/84.9/100.0
lotsize	2/0/1	<b>306.3</b>	<b>1.8</b>	136.7	46.7	-76.9/-72.2/-67.2/-77.5
mad	3/0/0	<b>7418.3</b>	0.1	<b>16.6</b>	0.0	40.0/0.0/-11.4/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>66.7</b>	<b>14.7</b>	<b>8.0</b>	<b>0.0</b>	-33.0/70.5/77.7/100.0
map16715-04	3/0/0	85.0	<b>21.5</b>	<b>8.7</b>	<b>0.0</b>	4.7/62.2/81.2/100.0

(continued)

Table A.22 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>33.0</b>	<b>0.1</b>	<b>9.0</b>	<b>0.0</b>	93.1/50.0/90.0/100.0
mas76	0/3/0	<b>13.6</b>	<b>0.1</b>	<b>5.3</b>	<b>0.0</b>	87.1/50.0/94.2/100.0
mc11	3/0/0	111.9	0.4	44.0	13.3	-3.3/0.0/-3.2/-7.5
mcsched	3/0/0	<b>7.9</b>	<b>0.6</b>	<b>5.0</b>	0.0	38.8/-16.7/-28.0/0.0
mik-250-20-75-4	0/3/0	<b>0.5</b>	<b>0.1</b>	<b>6.7</b>	<b>0.0</b>	99.2/50.0/82.5/100.0
milo-v12-6-r2-40-1	3/0/0	<b>122.8</b>	0.9	41.6	11.5	18.3/0.0/1.0/4.2
misc07	3/0/0	<b>53.2</b>	<b>0.2</b>	<b>24.4</b>	<b>0.3</b>	-46.2/-50.0/-17.6/-100.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>7.3</b>	<b>0.1</b>	<b>6.0</b>	0.0	47.9/66.7/69.4/0.0
modglob	3/0/0	<b>50.8</b>	0.1	<b>6.0</b>	<b>0.0</b>	52.0/0.0/80.8/100.0
momentum1	0/2/1	199.2	<b>74.5</b>	1031.9	531.1	-2.9/-47.0/-45.9/-33.5
msc98-ip	3/0/0	<b>11.2</b>	5.9	31.7	<b>1.0</b>	27.7/6.3/-3.2/-40.0
mushroom-best	0/3/0	<b>7.01e06</b>	<b>19.2</b>	<b>48.6</b>	<b>0.4</b>	23.6/-29.2/-17.7/76.5
mzzv11	0/3/0	<b>24.3</b>	<b>3.1</b>	<b>16.9</b>	0.0	-17.3/26.2/12.4/0.0
mzzv42z	0/3/0	<b>26.6</b>	<b>1.9</b>	<b>7.0</b>	<b>0.0</b>	14.2/61.2/70.6/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>15.3</b>	<b>0.4</b>	<b>29.2</b>	<b>0.6</b>	-38.6/-25.0/-30.1/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>17.8</b>	<b>1.2</b>	<b>4.6</b>	<b>0.0</b>	-94.9/75.5/82.6/100.0
neos-1171737	3/0/0	<b>11.2</b>	<b>0.4</b>	<b>4.3</b>	<b>0.0</b>	-65.2/75.0/85.5/100.0
neos-1354092	0/3/0	<b>9.6</b>	<b>102.4</b>	<b>24.3</b>	0.0	47.0/41.9/35.4/0.0
neos-1445765	3/0/0	33.2	<b>0.6</b>	<b>4.9</b>	0.0	6.2/25.0/12.5/0.0
neos-1456979	0/2/1	<b>114.9</b>	<b>29.9</b>	408.9	84.5	23.3/26.0/11.6/12.4
neos-1582420	0/3/0	73.2	<b>2.1</b>	<b>123.1</b>	<b>18.2</b>	-5.7/-28.6/-35.4/-48.4
neos-2657525-crna	0/3/0	960.8	<b>0.1</b>	<b>23.9</b>	<b>0.3</b>	5.5/50.0/42.8/85.0
neos-2746589-doon	0/0/3	<b>8.2</b>	<b>1040.1</b>	711.6	23.2	76.5/-86.7/-65.1/25.9
neos-2978193-inde	3/0/0	<b>3.9</b>	0.2	<b>3.6</b>	0.0	-15.4/0.0/-36.1/0.0
neos-2987310-joes	3/0/0	<b>0.2</b>	10.0	56.3	13.5	33.3/-5.0/-3.6/8.8
neos-3004026-krka	0/0/3	0.0	114.8	1276.6	4.2	0.0/-5.1/0.7/-14.3
neos-3024952-loue	0/1/2	886.3	<b>145.2</b>	1429.2	19.0	-8.3/-45.0/-1.0/31.7
neos-3046615-murg	0/3/0	<b>1750.5</b>	0.2	100.2	68.2	83.9/0.0/-5.9/-3.8
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/2/1	<b>135.4</b>	<b>132.0</b>	969.8	118.5	-10.7/71.2/11.5/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>24.1</b>	1041.9	0.4	0.0/-24.1/1.1/63.6
neos-3402294-bobin	3/0/0	<b>316.5</b>	<b>27.9</b>	<b>24.9</b>	0.0	26.3/-28.0/-23.3/0.0
neos-3555904-turama	2/1/0	2.0	<b>120.1</b>	<b>73.5</b>	<b>1.3</b>	0.0/-34.9/-57.3/-69.2
neos-3627168-kasai	3/0/0	<b>1.1</b>	0.1	22.0	<b>0.3</b>	26.7/0.0/-7.3/-100.0
neos-3656078-kumeu	0/0/3	29.7	153.0	1200.9	0.0	3.6/-8.3/-13.3/100.0
neos-3754480-nidda	3/0/0	<b>2.19e05</b>	<b>0.1</b>	<b>19.9</b>	<b>0.0</b>	-99.8/50.0/70.6/100.0
neos-4300652-rahue	0/0/3	280.3	<b>672.9</b>	790.0	0.3	-5.2/-38.6/-55.1/0.0
neos-4338804-snowy	0/3/0	<b>8487.8</b>	0.8	103.3	<b>32.6</b>	92.6/0.0/-2.7/-14.1
neos-4387871-tavua	0/1/2	<b>896.8</b>	21.3	913.6	495.5	-15.8/7.0/-12.2/-13.7
neos-4413714-turia	3/0/0	<b>87.1</b>	<b>18.7</b>	<b>7.0</b>	<b>0.0</b>	-49.6/76.6/91.2/100.0
neos-4532248-waihi	1/0/2	947.6	<b>377.3</b>	347.6	41.2	0.2/22.8/20.9/-12.4
neos-4647030-tutaki	3/0/0	<b>38.5</b>	<b>19.7</b>	<b>20.4</b>	0.0	-42.9/-11.2/-13.2/0.0
neos-4722843-widden	0/3/0	<b>19.5</b>	<b>72.0</b>	<b>119.8</b>	<b>21.3</b>	90.1/-23.5/-22.9/16.8
neos-4738912-atrato	0/3/0	<b>7.4</b>	0.3	<b>14.3</b>	0.0	38.3/0.0/-13.3/0.0
neos-4763324-toguru	3/0/0	59.3	<b>15.9</b>	<b>10.7</b>	0.0	-0.2/24.6/54.9/0.0
neos-4954672-berkel	3/0/0	<b>79.0</b>	0.1	<b>14.6</b>	<b>0.0</b>	-30.8/0.0/54.4/100.0
neos-5049753-cuanza	0/2/1	<b>48.2</b>	<b>909.2</b>	402.2	125.8	36.2/-15.3/-19.0/-42.8
neos-5052403-cygnnet	3/0/0	<b>1.0</b>	40.8	2.3	0.0	23.1/3.1/0.0/0.0
neos-5093327-huahum	3/0/0	<b>39.4</b>	<b>4.2</b>	<b>47.3</b>	<b>15.3</b>	95.7/68.7/60.8/82.3
neos-5104907-jarama	0/0/3	142.2	2018.4	779.1	185.6	-/-/-/-
neos-5107597-kakapo	3/0/0	<b>15856.8</b>	<b>3.0</b>	<b>217.8</b>	<b>181.1</b>	59.7/-40.0/-43.4/-47.6
neos-5114902-kasavu	0/3/0	49.7	2740.5	160.2	39.6	-/-/-/-
neos-5188808-nattai	3/0/0	<b>4618.0</b>	<b>4.6</b>	<b>20.5</b>	0.0	-13.1/19.3/23.2/0.0
neos-5195221-niemur	3/0/0	801.9	<b>13.9</b>	<b>23.2</b>	0.0	-4.2/-46.8/-19.4/0.0

(continued)

Table A.22 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	<b>314.5</b>	<b>3.5</b>	<b>9.8</b>	<b>0.0</b>	-29.1/45.3/49.2/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>3.93e05</b>	114.2	<b>81.5</b>	<b>24.9</b>	-24.7/-9.5/-15.0/-16.9
neos-860300	3/0/0	<b>81.2</b>	<b>1.0</b>	<b>12.7</b>	0.0	-29.8/-60.0/-68.5/0.0
neos-873061	3/0/0	<b>50.7</b>	24.4	31.3	<b>1.3</b>	17.2/5.1/1.3/18.8
neos-911970	3/0/0	<b>246.7</b>	<b>0.1</b>	<b>19.6</b>	<b>0.0</b>	-46.5/50.0/60.8/100.0
neos-933966	3/0/0	<b>19.5</b>	<b>4.8</b>	10.1	0.0	91.3/-66.7/-6.9/0.0
neos-950242	3/0/0	<b>16.4</b>	<b>10.5</b>	<b>35.3</b>	<b>0.8</b>	87.2/-36.2/-38.2/-50.0
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	1/2/0	2.4	<b>25.3</b>	<b>90.3</b>	2.2	-4.2/-20.2/-31.5/-4.5
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	1.4	<b>11.2</b>	1227.7	4.1	0.0/-17.0/-4.8/-36.6
neos17	3/0/0	320.8	0.2	<b>37.2</b>	<b>3.5</b>	-9.5/0.0/-14.8/-54.3
neos20	0/0/3	<b>59.5</b>	<b>12.0</b>	1381.0	93.4	-23.2/-18.3/-14.4/-12.8
neos5	3/0/0	<b>48.4</b>	0.1	<b>2.9</b>	0.0	-14.0/0.0/23.7/0.0
neos7	0/3/0	<b>13.8</b>	<b>0.1</b>	<b>4.6</b>	0.0	-20.3/50.0/81.6/0.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>1.7</b>	<b>4.9</b>	25.5	0.0	95.6/-12.2/0.8/0.0
netdiversion	3/0/0	<b>100.3</b>	<b>169.3</b>	<b>15.1</b>	0.0	-13.9/-55.8/-36.4/0.0
nexp-150-20-8-5	3/0/0	145.9	<b>0.3</b>	<b>3.0</b>	0.0	0.0/40.0/57.1/0.0
nh97p	0/0/3	10.6	<b>16.4</b>	977.6	200.3	-3.8/-17.1/10.5/22.7
nh97t	0/0/3	11.6	<b>25.3</b>	1383.7	323.9	-8.6/-49.4/-21.1/0.8
noswot	0/3/0	<b>0.5</b>	0.1	<b>9.8</b>	<b>0.4</b>	94.8/0.0/71.4/69.2
ns1116954	0/0/3	0.0	<b>847.3</b>	980.7	2.0	0.0/-44.3/-52.4/37.5
ns1208400	1/1/1	0.0	<b>71.9</b>	447.5	0.8	0.0/20.2/-11.6/-62.5
ns1644855	3/0/0	<b>21.6</b>	<b>189.0</b>	<b>5.0</b>	<b>0.0</b>	-97.7/51.6/85.5/100.0
ns1760995	3/0/0	<b>27.2</b>	<b>14.7</b>	<b>12.0</b>	<b>0.0</b>	-45.2/82.6/85.1/100.0
ns1830653	0/2/1	<b>525.9</b>	<b>15.2</b>	520.4	47.0	-68.8/-71.1/-88.7/-97.9
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ipx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.3	<b>0.1</b>	<b>3.0</b>	0.0	0.0/66.7/84.2/0.0
nursesched-medium-hint03	0/3/0	<b>1077.1</b>	<b>72.4</b>	<b>40.9</b>	0.0	-27.0/-80.8/-72.1/0.0
nursesched-sprint02	0/3/0	<b>39.4</b>	<b>3.0</b>	<b>14.9</b>	0.0	28.6/-36.7/-37.6/0.0
nw04	3/0/0	3.9	<b>1.4</b>	<b>4.9</b>	0.0	0.0/30.0/38.7/0.0
opm2-z10-s4	3/0/0	94.2	27.2	1.0	0.0	0.0/0.4/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	0.1	<b>5.6</b>	<b>0.0</b>	100.0/0.0/84.6/100.0
p200x1188c	3/0/0	3.9	0.2	31.0	1.0	0.0/0.0/0.0/0.0
p2756	0/3/0	75.2	0.1	5.0	0.0	8.4/0.0/0.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/-
pg	3/0/0	<b>4.0</b>	<b>0.1</b>	<b>14.4</b>	<b>0.0</b>	74.2/66.7/72.1/100.0
pg5-34	3/0/0	7.6	<b>0.1</b>	<b>7.4</b>	<b>0.0</b>	-6.6/75.0/85.8/100.0
physiciansched3-3	2/1/0	<b>197.2</b>	<b>45.7</b>	<b>145.2</b>	<b>7.0</b>	-95.6/16.1/-68.3/-85.7
physiciansched6-2	0/0/3	<b>3.6</b>	<b>61.4</b>	852.7	80.3	26.5/27.3/-13.2/-56.7
piperout-08	0/0/3	<b>575.4</b>	<b>58.2</b>	1378.7	22.6	-31.4/15.9/19.4/32.1
piperout-27	0/0/3	<b>294.7</b>	<b>56.4</b>	1024.3	17.1	-22.5/14.5/14.4/2.8
pk1	3/0/0	<b>604.9</b>	<b>0.1</b>	<b>35.4</b>	<b>1.3</b>	49.2/50.0/39.0/85.4
pp08a	3/0/0	<b>48.0</b>	0.1	17.3	0.0	17.8/0.0/-9.8/0.0
pp08aCUTS	3/0/0	<b>43.6</b>	0.1	10.9	0.0	-19.5/0.0/9.2/0.0
proteindesign121hz512p9	0/3/0	<b>5.7</b>	<b>54.8</b>	<b>243.4</b>	<b>16.5</b>	-57.9/-90.9/-90.0/-98.2
proteindesign122trx11p8	0/2/1	<b>1.9</b>	<b>26.8</b>	121.6	6.6	-42.1/-96.3/-96.7/-100.0
protfold	3/0/0	<b>57.9</b>	<b>7.5</b>	<b>51.6</b>	<b>1.4</b>	12.3/10.7/-26.7/-100.0
qap10	3/0/0	19.4	<b>18.3</b>	<b>4.0</b>	0.0	0.0/-25.1/-50.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	<b>283.2</b>	0.5	22.8	0.0	-15.2/0.0/9.9/0.0
rB10-011001	3/0/0	<b>253.3</b>	0.5	<b>22.0</b>	0.0	-19.4/0.0/16.3/0.0
rB11-010000	3/0/0	269.3	1.4	31.0	<b>1.0</b>	6.7/-7.1/-3.2/-40.0
rB11-110001	3/0/0	214.3	2.6	22.5	<b>0.0</b>	-3.2/0.0/3.4/100.0
rB12-111111	0/1/2	90.6	44.5	650.5	5.4	-0.8/4.1/-11.6/-40.7
rC10-001000	3/0/0	<b>174.7</b>	<b>0.3</b>	29.8	0.0	36.5/-33.3/-6.4/0.0

(continued)

Table A.22 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
rC10-100001	3/0/0	490.2	5.1	103.1	2.6	-16.7/-3.9/-1.6/-69.2
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	470.4	6.8	46.8	1.5	-31.6/-25.0/-22.2/-46.7
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	346.2	4.7	182.1	28.6	-56.1/-61.7/-62.5/-87.4
radiationm40-10-02	0/3/0	4677.7	26.5	299.1	39.4	-90.8/-38.9/-51.9/-77.2
rail01	3/0/0	37.7	1725.5	17.7	0.0	-17.8/-25.8/-32.8/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	37.4	0.3	23.5	0.8	-55.6/0.0/-3.0/-62.5
rd-rplusc-21	0/0/3	57.0	42.2	1061.8	432.5	1.9/-14.2/-18.4/-16.6
reblock115	3/0/0	12.1	1.4	52.5	6.1	-7.4/12.5/5.2/1.6
rmatr100-p10	3/0/0	2.0	0.9	4.9	0.0	93.2/-33.3/-53.1/0.0
rmatr200-p5	3/0/0	16.5	31.5	6.3	0.0	15.4/-55.2/-68.3/0.0
rocl-4-11	0/0/3	54.9	20.2	868.5	118.1	20.7/4.7/6.8/-12.1
rocll-5-11	0/3/0	79.3	21.6	422.2	126.5	12.3/-61.1/-63.0/-58.4
roi2alpha3n4	3/0/0	48.0	7.2	7.0	0.0	23.1/78.4/79.6/100.0
roi5alpha10n8	3/0/0	56.6	97.1	8.0	0.0	5.8/78.3/72.4/0.0
roll3000	0/3/0	35.6	1.2	68.3	14.4	-26.4/-8.3/-29.1/-68.8
rout	0/3/0	45.3	0.2	39.9	4.2	8.5/0.0/-11.8/-59.5
s100	3/0/0	6.2	299.6	13.9	0.0	-72.6/1.0/-52.5/0.0
s250r10	3/0/0	0.1	52.0	2.0	0.0	0.0/2.6/0.0/0.0
satellites2-40	0/3/0	167.6	160.2	147.0	57.0	31.7/-72.4/-76.3/-95.3
satellites2-60-fs	0/1/2	223.5	252.1	425.1	189.9	-60.0/-91.0/-91.8/-98.6
savsched1	0/3/0	13.5	147.4	8.3	0.0	-41.5/22.5/32.5/0.0
sct2	3/0/0	52.0	0.2	7.2	0.0	-43.8/66.7/72.4/100.0
set1ch	3/0/0	91.7	0.1	31.0	1.0	-6.7/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	3.2	1.6	3.0	0.0	-56.3/40.7/60.5/0.0
sing326	3/0/0	64.2	13.0	8.6	0.0	-83.5/47.4/74.7/100.0
sing44	3/0/0	17.9	10.4	4.6	0.0	-58.7/60.6/88.1/100.0
snp-Q2-004-104	0/3/0	224.5	21.8	33.0	1.0	-99.2/-9.6/1.8/47.4
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.3	1.3	0.0/0.0/0.0/0.0
sp97ar	3/0/0	25.7	1.0	2.2	0.0	3.4/-10.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.0	53.3	9.0	0.0	-0.4/14.2/30.8/0.0
square41	0/3/0	10.8	1477.8	11.9	0.0	-38.0/-17.4/-16.0/0.0
square47	0/1/0	6.3	3550.3	15.0	0.0	-/-/-/-
supportcase10	3/0/0	26.1	99.5	8.8	0.0	84.7/9.6/35.3/0.0
supportcase12	0/3/0	5.3	4.6	4.0	0.0	-66.0/68.5/81.0/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	37.2	0.2	77.0	46.7	99.6/0.0/14.2/26.2
supportcase33	0/3/0	66.8	16.5	175.2	47.6	-3.4/-16.4/-30.8/-69.5
supportcase40	3/0/0	164.8	1.8	8.0	0.0	-89.3/57.1/51.8/0.0
supportcase42	0/3/0	18.4	3.8	7.3	0.0	24.6/9.5/37.1/0.0
supportcase6	3/0/0	0.4	5.7	5.3	0.0	0.0/57.1/55.8/0.0
supportcase7	3/0/0	15.1	5.4	11.9	0.0	-5.3/34.9/54.2/0.0
swath	0/3/0	181.7	48.7	562.6	214.4	-0.1/-72.3/-66.6/-72.2
swath1	3/0/0	31.4	1.0	37.7	4.0	48.0/56.5/39.4/74.5
swath3	3/0/0	18.8	1.0	37.7	3.6	43.4/33.3/12.1/-11.1
t1717	3/0/0	186.2	123.0	64.7	0.7	-3.8/2.6/-32.8/-100.0
tbfp-network	3/0/0	9.7	11.9	14.3	0.0	95.1/46.9/-2.1/0.0
thor50dday	3/0/0	307.3	7.9	26.0	1.9	-16.1/-8.9/-5.8/-10.5
timtab1	0/3/0	48.7	0.3	61.1	11.0	12.3/50.0/46.3/60.6
timtab2	0/1/2	75.8	10.0	918.6	335.5	-2.9/-42.0/-13.8/-19.4
tr12-30	3/0/0	42.5	0.2	34.0	3.8	41.7/0.0/-6.8/-57.9
traininstance2	0/2/1	157.4	4.2	639.1	67.0	35.4/-21.4/1.6/2.3
traininstance6	0/3/0	80.2	0.9	227.4	23.1	82.6/25.0/25.7/45.1
trento1	3/0/0	100.8	16.9	16.3	0.0	46.1/-52.7/-42.9/0.0

(continued)

Table A.22 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
triptim1	0/3/0	0.1	21.4	3.6	0.0	0.0/8.2/10.0/0.0
uccase12	3/0/0	<b>2.8</b>	10.8	16.6	0.0	-32.1/-4.6/-6.0/0.0
uccase9	3/0/0	<b>387.4</b>	<b>11.2</b>	27.5	2.8	93.1/80.7/85.5/96.2
uct-subprob	3/0/0	<b>20.4</b>	<b>0.4</b>	7.3	0.0	-39.2/33.3/5.2/0.0
unitcal-7	0/0/3	<b>23.0</b>	<b>107.1</b>	780.2	72.6	14.2/22.2/21.3/50.2
var-smallemerly-m6j6	3/0/0	<b>24.9</b>	<b>3.3</b>	<b>6.3</b>	<b>0.0</b>	90.3/86.2/90.7/100.0
vpm2	3/0/0	42.4	0.1	<b>27.2</b>	<b>0.3</b>	5.8/0.0/-25.0/-100.0
wachplan	0/3/0	0.0	<b>1.9</b>	<b>21.4</b>	0.0	0.0/36.7/19.2/0.0
Geom. means		(271 instances)	(228 instances)			
FP		45.7	5.4	15.9	1.2	
FP+(3,l,g,c, $\Delta$ )		<b>43.1</b>	<b>5.3</b>	<b>12.7</b>	<b>0.9</b>	

Table A.23.: Performance of FP+(3,l,h,c, $\Delta$ )

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	2/1/0	<b>8.7</b>	<b>4.9</b>	<b>96.4</b>	1.3	28.1/59.8/39.6/-7.7
30n20b8	0/3/0	<b>730.5</b>	6.3	<b>227.3</b>	<b>37.9</b>	-36.7/-9.5/-26.5/-23.7
50v-10	0/3/0	<b>145.2</b>	<b>0.2</b>	<b>18.4</b>	<b>0.0</b>	-14.1/33.3/20.0/100.0
CMS750-4	3/0/0	<b>73.6</b>	<b>5.4</b>	<b>90.4</b>	<b>14.5</b>	-28.0/-24.1/-28.0/-17.2
a1c1s1	3/0/0	<b>23.6</b>	<b>0.7</b>	31.3	1.3	55.3/-42.9/0.0/0.0
academicitimetablesmall	0/0/2	inf	559.2	1050.6	0.0	-/-/-/-
aflow30a	3/0/0	131.6	0.1	34.2	<b>2.8</b>	0.0/0.0/-2.0/-28.6
aflow40b	3/0/0	<b>295.6</b>	0.3	34.9	<b>2.8</b>	-29.9/0.0/-8.3/-46.4
air04	3/0/0	<b>4.2</b>	<b>3.8</b>	<b>30.5</b>	<b>1.0</b>	-97.6/-31.6/-78.4/-100.0
air05	3/0/0	<b>2.5</b>	<b>0.7</b>	4.0	0.0	39.0/12.5/0.0/0.0
app1-1	3/0/0	<b>53.0</b>	0.5	32.3	<b>1.9</b>	-94.2/0.0/6.6/52.5
app1-2	2/1/0	43.9	10.9	56.1	<b>18.3</b>	0.0/-1.8/-7.7/-16.4
arki001	0/1/2	2.8	22.3	834.0	217.9	3.4/-7.2/-3.6/-14.5
assign1-5-8	3/0/0	<b>4.2</b>	0.1	<b>5.6</b>	0.0	-54.8/0.0/74.9/0.0
atlanta-ip	3/0/0	<b>15.9</b>	<b>14.8</b>	23.3	<b>0.3</b>	11.7/12.4/9.7/50.0
b1c1s1	3/0/0	<b>87.5</b>	<b>0.7</b>	35.0	<b>4.3</b>	45.8/-28.6/-3.7/-16.3
bab2	0/0/3	<b>20.8</b>	<b>939.4</b>	819.2	232.9	18.4/-66.6/-78.9/-89.9
bab6	2/1/0	<b>13.4</b>	<b>78.0</b>	81.6	<b>7.7</b>	43.5/25.3/7.0/49.7
beasleyC3	3/0/0	10.7	0.2	35.7	<b>5.6</b>	7.8/0.0/-2.0/-14.3
binkar10-1	3/0/0	<b>1.7</b>	0.1	14.3	0.0	57.5/0.0/8.9/0.0
blp-ar98	3/0/0	70.5	1.8	<b>14.8</b>	0.0	1.1/10.0/12.4/0.0
blp-ic98	3/0/0	36.3	0.4	2.2	0.0	2.7/0.0/0.0/0.0
bnatt400	0/0/1	0.0	289.4	1347.0	0.0	-/-/-/-
bppc4-08	3/0/0	54.5	<b>0.1</b>	<b>5.3</b>	<b>0.0</b>	-5.3/91.7/91.5/100.0
brazil3	0/3/0	<b>306.9</b>	<b>43.6</b>	<b>46.9</b>	<b>0.3</b>	51.6/-51.6/-54.4/-100.0
buildingenergy	0/3/0	<b>0.9</b>	<b>167.7</b>	<b>4.0</b>	0.0	18.2/75.9/65.8/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.8	41.3	<b>11.3</b>	0.0/-3.6/-3.1/-11.5
chromaticindex1024-7	3/0/0	0.0	<b>61.7</b>	<b>6.3</b>	0.0	0.0/-11.2/-52.4/0.0
chromaticindex512-7	3/0/0	0.0	<b>75.9</b>	<b>6.3</b>	0.0	0.0/-40.7/-68.3/0.0
cmflsp50-24-8-8	1/2/0	18.5	<b>23.4</b>	168.2	36.5	5.1/86.0/84.0/87.6
co-100	3/0/0	<b>395.1</b>	<b>7.0</b>	<b>17.9</b>	0.0	-23.4/-12.9/-12.8/0.0
cod105	3/0/0	100.0	1.8	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	<b>2936.5</b>	<b>16.6</b>	<b>55.8</b>	<b>0.4</b>	14.3/-62.7/-57.0/-100.0
comp21-2idx	0/3/0	394.4	<b>13.9</b>	<b>61.5</b>	<b>0.8</b>	7.6/-66.9/-59.2/-100.0
cost266-UUE	3/0/0	36.9	0.4	24.3	<b>0.8</b>	-4.9/0.0/-3.3/-62.5
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/0/3	74.7	<b>13.3</b>	1284.6	340.8	-7.6/-54.1/-70.2/-85.5
csched008	0/2/1	9.8	<b>4.0</b>	496.0	153.1	0.0/-57.5/-69.4/-84.3
cvs16r128-89	3/0/0	97.9	1.0	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	19.6	<b>2.0</b>	0.0	0.0/-4.6/87.7/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>21.1</b>	<b>2.0</b>	<b>0.0</b>	-33.3/52.0/93.4/100.0

(continued)

Table A.23 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
dano3mip	3/0/0	<b>15.4</b>	<b>25.6</b>	<b>5.0</b>	<b>0.0</b>	10.5/90.9/92.9/100.0
danoint	3/0/0	<b>22.1</b>	<b>0.8</b>	<b>42.9</b>	<b>8.0</b>	96.6/80.0/61.5/80.6
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>8.2</b>	<b>0.5</b>	<b>18.0</b>	0.0	-31.7/-40.0/-27.8/0.0
drayage-25-23	3/0/0	<b>6.7</b>	<b>0.2</b>	<b>5.0</b>	0.0	34.3/50.0/69.5/0.0
ds	3/0/0	4945.0	6.1	1.0	0.0	0.0/-1.6/0.0/0.0
dws008-01	0/0/3	<b>49.5</b>	<b>58.5</b>	816.2	238.1	48.4/21.6/0.4/-1.0
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	1.1	1.0	0.0	0.0/0.0/0.0/0.0
enlight-hard	0/0/3	0.0	3.2	697.4	197.5	-/-/-/-
exp-1-500-5-5	3/0/0	<b>160.9</b>	0.1	24.9	<b>0.3</b>	-53.1/0.0/7.4/-100.0
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>642.5</b>	<b>0.7</b>	<b>42.6</b>	<b>2.3</b>	29.2/-42.9/-52.3/-100.0
fhnw-binpack4-48	0/0/1	0.0	45.0	1804.0	258.0	-/-/-/-
fiball	0/3/0	<b>13.8</b>	<b>2.0</b>	<b>12.2</b>	<b>0.0</b>	19.8/71.4/78.2/100.0
fiber	3/0/0	<b>126.5</b>	0.1	14.0	0.0	17.6/0.0/6.0/0.0
fixnet6	3/0/0	<b>54.7</b>	0.1	31.0	1.0	-22.1/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	11.3	0.1	2.9	0.0	-7.1/0.0/0.0/0.0
germanrr	0/3/0	<b>3.0</b>	<b>9.5</b>	<b>56.9</b>	<b>7.7</b>	26.8/18.8/-10.7/-23.4
gesa2	0/3/0	2.6	0.2	20.4	0.0	-7.7/0.0/0.0/0.0
gesa2-o	0/3/0	<b>17.4</b>	0.2	34.8	<b>1.3</b>	13.0/0.0/2.2/13.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.6	1.0	0.0	0.0/0.0/0.0/0.0
glass4	3/0/0	<b>187.2</b>	<b>0.2</b>	<b>77.7</b>	<b>26.7</b>	72.5/33.3/25.4/17.1
gmu-35-40	3/0/0	<b>7.4</b>	0.1	<b>3.0</b>	0.0	-12.2/0.0/78.6/0.0
gmu-35-50	3/0/0	<b>15.2</b>	0.3	<b>21.8</b>	<b>1.9</b>	-19.7/0.0/30.6/-47.4
graph20-20-1rand	3/0/0	<b>22.2</b>	<b>2.8</b>	<b>28.0</b>	<b>0.0</b>	-36.9/31.7/10.5/100.0
graphdraw-domain	0/3/0	<b>56.4</b>	<b>0.1</b>	<b>15.8</b>	<b>0.3</b>	-48.9/66.7/74.0/97.1
h80x6320d	3/0/0	20.0	1.2	32.3	<b>2.3</b>	9.1/0.0/-0.9/-17.4
harp2	3/0/0	11.6	0.1	13.0	0.0	6.5/0.0/-2.3/0.0
highschool1-aigio	0/3/0	inf	<b>1198.9</b>	<b>54.6</b>	0.0	0.0/-42.6/-72.0/0.0
hypothyroid-k1	3/0/0	0.0	4.7	1.0	0.0	0.0/2.1/0.0/0.0
ic97p	0/0/3	15.2	<b>4.2</b>	671.5	187.2	1.3/17.6/24.3/8.9
ic97t	0/0/3	12.8	<b>3.3</b>	1010.9	282.0	-3.1/15.4/20.2/9.4
icir97p	0/0/3	<b>19.3</b>	<b>19.4</b>	855.3	205.3	15.7/10.2/25.0/4.8
icir97t	0/3/0	14.3	<b>5.1</b>	<b>181.0</b>	<b>101.3</b>	8.9/-13.7/14.0/21.4
irish-electricity	3/0/0	<b>7.2</b>	<b>10.3</b>	<b>7.0</b>	<b>0.0</b>	-16.7/46.9/71.1/100.0
irp	3/0/0	<b>2.5</b>	0.3	<b>2.8</b>	0.0	34.2/0.0/17.6/0.0
istanbul-no-cutoff	3/0/0	33.4	<b>4.5</b>	<b>13.9</b>	0.0	7.2/29.7/36.8/0.0
k1mushroom	3/0/0	18.2	40.4	1.0	0.0	0.0/-1.5/0.0/0.0
lectsched-5-obj	0/0/3	2394.3	<b>114.5</b>	1237.9	23.6	-6.2/-26.6/-26.6/-70.3
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>402.8</b>	<b>0.2</b>	<b>13.6</b>	<b>0.0</b>	40.3/81.8/84.9/100.0
lotsize	1/1/1	<b>360.4</b>	<b>2.0</b>	164.7	61.9	-80.4/-75.0/-72.7/-83.0
mad	3/0/0	<b>5972.2</b>	0.1	14.6	0.0	51.7/0.0/0.7/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>64.1</b>	<b>14.9</b>	<b>8.0</b>	<b>0.0</b>	-30.3/70.1/77.7/100.0
map16715-04	3/0/0	<b>69.6</b>	<b>20.7</b>	<b>8.7</b>	<b>0.0</b>	22.0/63.6/81.2/100.0
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>33.0</b>	<b>0.1</b>	<b>8.3</b>	<b>0.0</b>	93.1/50.0/90.8/100.0
mas76	0/3/0	<b>13.6</b>	<b>0.1</b>	<b>5.3</b>	<b>0.0</b>	87.1/50.0/94.2/100.0
mc11	3/0/0	112.4	0.4	43.6	13.3	-3.7/0.0/-2.3/-7.5
mcsched	3/0/0	<b>11.4</b>	0.5	<b>4.6</b>	0.0	11.6/0.0/-21.7/0.0
mik-250-20-75-4	0/3/0	<b>0.5</b>	<b>0.1</b>	<b>6.7</b>	<b>0.0</b>	99.2/50.0/82.5/100.0
milo-v12-6-r2-40-1	3/0/0	<b>122.8</b>	0.9	41.6	11.5	18.3/0.0/1.0/4.2
misc07	3/0/0	29.0	0.1	21.3	0.0	-1.4/0.0/-5.6/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0

(continued)



Table A.23 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
mod011	3/0/0	<b>7.3</b>	<b>0.1</b>	<b>6.0</b>	0.0	47.9/66.7/69.4/0.0
modglob	3/0/0	<b>50.8</b>	0.1	<b>6.0</b>	<b>0.0</b>	52.0/0.0/80.8/100.0
momentum1	0/0/3	<b>160.0</b>	<i>84.1</i>	1124.0	566.6	17.3/-53.0/-50.4/-37.7
msc98-ip	3/0/0	<b>9.7</b>	5.8	31.7	<b>1.0</b>	37.4/7.9/-3.2/-40.0
mushroom-best	0/3/0	8.35e06	<i>21.7</i>	<i>60.2</i>	<b>1.5</b>	8.9/-37.3/-33.6/11.8
mzzv11	0/3/0	<i>23.4</i>	<b>2.9</b>	<b>14.7</b>	0.0	-14.1/31.0/23.8/0.0
mzzv42z	0/3/0	<b>24.7</b>	<b>1.9</b>	<b>7.0</b>	<b>0.0</b>	20.3/61.2/70.6/100.0
n2seq36q	3/0/0	29.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	39.2	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>7.8</b>	<i>0.4</i>	<i>27.2</i>	<i>0.3</i>	17.0/-25.0/-25.0/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<i>17.8</i>	<b>1.2</b>	<b>4.6</b>	<b>0.0</b>	-94.9/75.5/82.6/100.0
neos-1171737	3/0/0	<i>12.6</i>	<b>0.4</b>	<b>4.6</b>	<b>0.0</b>	-69.0/75.0/84.5/100.0
neos-1354092	0/3/0	<b>11.6</b>	<b>109.5</b>	<b>26.6</b>	0.0	35.9/37.9/29.3/0.0
neos-1445765	3/0/0	33.8	<b>0.6</b>	5.2	0.0	4.5/25.0/7.1/0.0
neos-1456979	0/2/1	<b>80.6</b>	38.9	551.0	93.7	46.2/3.7/-16.1/2.9
neos-1582420	0/3/0	<i>104.3</i>	<i>6.2</i>	<i>377.0</i>	<i>71.0</i>	-33.8/-75.8/-78.9/-86.8
neos-2657525-crna	0/3/0	<i>1141.4</i>	<i>0.8</i>	<i>88.0</i>	<i>3.7</i>	-11.0/-75.0/-52.5/-45.9
neos-2746589-doon	0/0/3	<b>11.9</b>	<i>692.5</i>	725.3	31.5	65.9/-80.1/-65.8/-0.6
neos-2978193-inde	3/0/0	<i>3.9</i>	0.2	<i>3.6</i>	0.0	-15.4/0.0/-36.1/0.0
neos-2987310-joes	2/1/0	<i>1.4</i>	<i>12.1</i>	<i>66.4</i>	<i>18.1</i>	-78.6/-21.5/-18.2/-18.2
neos-3004026-krka	0/0/3	0.0	<b>88.5</b>	1122.5	3.9	0.0/18.8/12.7/-7.7
neos-3024952-loue	0/1/2	<i>908.2</i>	<i>142.1</i>	1395.8	24.8	-10.5/-43.8/1.3/10.8
neos-3046615-murg	0/3/0	<b>1287.1</b>	0.2	<i>105.7</i>	<i>72.9</i>	88.2/0.0/-10.8/-10.0
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	130.2	<b>134.7</b>	920.9	69.3	-7.1/70.6/16.0/-100.0
neos-3381206-awhea	0/0/3	4.9	<i>20.6</i>	897.7	0.0	0.0/-11.2/14.8/100.0
neos-3402294-bobin	3/0/0	<i>530.4</i>	<i>32.0</i>	<i>30.2</i>	<i>0.3</i>	-19.1/-37.2/-36.8/-100.0
neos-3555904-turama	2/0/1	<i>4.3</i>	<i>197.6</i>	98.2	5.2	-53.5/-60.4/-68.0/-92.3
neos-3627168-kasai	3/0/0	<b>1.3</b>	0.1	22.0	<i>0.3</i>	13.3/0.0/-7.3/-100.0
neos-3656078-kumeu	0/0/3	31.4	<i>177.9</i>	1296.4	0.0	-1.9/-21.1/-19.7/100.0
neos-3754480-nidda	3/0/0	<i>10382.1</i>	<b>0.1</b>	<b>21.6</b>	<b>0.0</b>	-96.5/50.0/68.1/100.0
neos-4300652-rahue	0/1/2	<b>225.9</b>	<b>367.0</b>	379.4	1.0	15.0/11.1/-6.5/-70.0
neos-4338804-snowy	0/3/0	<b>32229.3</b>	0.8	102.1	<i>32.3</i>	71.7/0.0/-1.6/-13.3
neos-4387871-tavua	0/1/2	<i>939.7</i>	<b>18.4</b>	788.3	434.5	-19.7/19.7/1.7/-1.6
neos-4413714-turia	3/0/0	<i>87.1</i>	<b>18.7</b>	<b>7.0</b>	<b>0.0</b>	-49.6/76.6/91.2/100.0
neos-4532248-waihi	0/0/3	949.4	<i>620.0</i>	860.2	244.1	0.0/-21.1/-48.9/-85.2
neos-4647030-tutaki	3/0/0	<b>16.5</b>	<b>15.2</b>	<b>15.1</b>	0.0	25.0/13.1/14.7/0.0
neos-4722843-widden	0/3/0	<b>96.9</b>	<i>81.1</i>	<i>133.2</i>	<i>33.3</i>	51.0/-32.1/-30.6/-23.1
neos-4738912-atrato	0/3/0	<b>7.4</b>	0.3	<i>14.3</i>	0.0	38.3/0.0/-13.3/0.0
neos-4763324-toguru	3/0/0	53.8	<b>16.0</b>	<b>11.0</b>	0.0	9.1/24.2/53.6/0.0
neos-4954672-berkel	3/0/0	<i>81.2</i>	0.1	<b>15.3</b>	<b>0.0</b>	-32.6/0.0/52.2/100.0
neos-5049753-cuanza	1/1/1	<b>63.5</b>	<i>919.9</i>	405.0	102.4	16.0/-16.3/-19.6/-29.7
neos-5052403-cygnat	3/0/0	<b>1.0</b>	40.8	2.3	0.0	23.1/3.1/0.0/0.0
neos-5093327-huahum	3/0/0	<b>28.7</b>	<b>5.1</b>	<b>58.2</b>	<b>25.8</b>	96.9/61.9/51.8/70.2
neos-5104907-jarama	0/1/2	66.4	1969.5	797.8	103.9	-/-/-/-
neos-5107597-kakapo	2/1/0	35936.2	<i>2.8</i>	<i>210.3</i>	<i>172.6</i>	8.6/-35.7/-41.4/-45.0
neos-5114902-kasavu	1/2/0	49.8	2908.3	167.0	46.1	-/-/-/-
neos-5188808-nattai	3/0/0	4297.8	<b>3.8</b>	<b>17.3</b>	0.0	-6.6/33.3/35.2/0.0
neos-5195221-niemur	3/0/0	<b>651.2</b>	<i>13.2</i>	<i>22.7</i>	0.0	15.2/-43.9/-17.6/0.0
neos-631710	3/0/0	149.4	2.4	1.0	0.0	0.0/4.0/0.0/0.0
neos-662469	0/3/0	<i>305.7</i>	<b>3.6</b>	<b>9.8</b>	<b>0.0</b>	-27.0/43.8/49.2/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	0.5	0.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<i>4.07e05</i>	<i>121.0</i>	<i>83.4</i>	<i>25.8</i>	-27.3/-14.6/-16.9/-19.8
neos-860300	3/0/0	58.6	<i>1.4</i>	<i>17.6</i>	0.0	-2.7/-71.4/-77.3/0.0
neos-873061	3/0/0	<b>48.9</b>	24.9	31.7	1.6	20.1/3.1/0.0/0.0
neos-911970	3/0/0	<i>257.9</i>	<b>0.1</b>	<b>20.3</b>	<b>0.0</b>	-48.8/50.0/59.4/100.0
neos-933966	3/0/0	<b>2.3</b>	<i>4.5</i>	<b>6.6</b>	0.0	99.0/-64.4/29.8/0.0
neos-950242	2/1/0	<b>27.4</b>	<i>17.4</i>	<i>50.0</i>	<i>2.2</i>	78.6/-61.5/-56.4/-81.8
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.23 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-960392	1/2/0	2.2	<b>29.5</b>	<b>100.8</b>	<b>4.5</b>	4.3/-31.5/-38.6/-53.3
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	1.4	8.9	901.2	15.0	0.0/4.3/22.9/-82.7
neos17	3/0/0	<b>418.0</b>	0.2	<b>38.1</b>	<b>3.8</b>	-30.6/0.0/-16.8/-57.9
neos20	0/1/2	<b>66.0</b>	<b>8.8</b>	1013.2	88.5	-30.8/10.2/14.3/-8.0
neos5	3/0/0	<b>49.7</b>	0.1	<b>2.9</b>	0.0	-16.3/0.0/23.7/0.0
neos7	0/3/0	<b>13.8</b>	<b>0.1</b>	<b>4.6</b>	0.0	-20.3/50.0/81.6/0.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>30.5</b>	<b>6.1</b>	<b>32.4</b>	<b>0.7</b>	20.4/-29.5/-20.7/-100.0
netdiversion	3/0/0	89.3	<b>171.3</b>	<b>14.6</b>	0.0	-3.2/-56.3/-34.2/0.0
nexp-150-20-8-5	3/0/0	145.9	<b>0.3</b>	<b>3.0</b>	0.0	0.0/40.0/57.1/0.0
nh97p	0/0/3	10.5	13.1	770.2	162.1	-2.9/3.7/29.5/37.4
nh97t	0/0/3	<b>9.4</b>	<b>30.0</b>	1683.4	452.0	11.3/-57.3/-35.1/-27.7
noswot	0/3/0	<b>0.5</b>	0.1	<b>10.0</b>	<b>0.4</b>	94.8/0.0/70.8/69.2
ns1116954	0/2/1	0.0	<b>1043.4</b>	1264.0	3.8	0.0/-54.8/-63.0/-15.8
ns1208400	1/1/1	0.0	<b>71.3</b>	413.5	0.7	0.0/20.9/-4.4/-57.1
ns1644855	3/0/0	<b>21.6</b>	<b>196.2</b>	<b>5.0</b>	<b>0.0</b>	-97.7/49.8/85.5/100.0
ns1760995	3/0/0	<b>45.7</b>	<b>15.7</b>	<b>12.6</b>	<b>0.0</b>	-67.4/81.4/84.3/100.0
ns1830653	1/2/0	<b>308.4</b>	<b>15.1</b>	<b>403.1</b>	<b>22.2</b>	-46.8/-70.9/-85.4/-95.5
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-idx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.3	<b>0.1</b>	<b>3.0</b>	0.0	0.0/66.7/84.2/0.0
nursesched-medium-hint03	0/3/0	737.5	<b>77.6</b>	<b>43.3</b>	<b>0.3</b>	6.2/-82.1/-73.7/-100.0
nursesched-sprint02	0/3/0	<b>41.0</b>	<b>3.1</b>	<b>15.9</b>	0.0	25.7/-38.7/-41.5/0.0
nw04	3/0/0	3.9	<b>1.5</b>	<b>5.5</b>	0.0	0.0/25.0/31.2/0.0
opm2-z10-s4	3/0/0	94.2	27.1	1.0	0.0	0.0/0.7/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	0.1	<b>5.6</b>	<b>0.0</b>	100.0/0.0/84.6/100.0
p200x1188c	3/0/0	3.9	0.2	31.0	1.0	0.0/0.0/0.0/0.0
p2756	0/3/0	75.2	0.1	5.0	0.0	8.4/0.0/0.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/-
pg	3/0/0	<b>5.9</b>	<b>0.1</b>	<b>11.8</b>	<b>0.0</b>	61.9/66.7/77.2/100.0
pg5-34	3/0/0	7.6	<b>0.1</b>	<b>7.4</b>	<b>0.0</b>	-6.6/75.0/85.8/100.0
physiciansched3-3	0/3/0	<b>672.1</b>	<b>107.7</b>	<b>493.2</b>	<b>46.6</b>	-98.7/-49.4/-90.7/-97.9
physiciansched6-2	0/0/3	<b>3.4</b>	<b>64.9</b>	881.8	107.1	30.6/23.1/-16.1/-67.5
piperout-08	0/0/3	<b>301.1</b>	<b>80.4</b>	1858.6	23.2	23.8/-13.9/-7.9/30.3
piperout-27	0/0/3	<b>612.5</b>	<b>81.4</b>	1508.4	26.2	-62.7/-18.9/-20.7/-32.8
pk1	3/0/0	<b>515.0</b>	<b>0.1</b>	<b>34.0</b>	<b>0.8</b>	56.8/50.0/41.4/91.0
pp08a	3/0/0	55.4	0.1	<b>19.3</b>	0.0	5.1/0.0/-19.2/0.0
pp08aCUTS	3/0/0	<b>30.2</b>	0.1	11.6	0.0	14.0/0.0/3.3/0.0
proteindesign121hz512p9	0/2/1	<b>5.2</b>	<b>113.6</b>	484.3	35.4	-53.8/-95.6/-95.0/-99.2
proteindesign122trx11p8	0/3/0	<b>2.8</b>	<b>14.0</b>	<b>66.3</b>	<b>3.8</b>	-60.7/-92.9/-94.0/-100.0
protfold	3/0/0	68.0	<b>6.9</b>	<b>43.0</b>	<b>0.6</b>	-2.9/17.9/-12.1/-100.0
qap10	3/0/0	<b>17.1</b>	<b>18.0</b>	<b>4.0</b>	0.0	11.9/-23.9/-50.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	<b>277.9</b>	0.5	<b>21.4</b>	0.0	-13.6/0.0/15.4/0.0
rB10-011001	3/0/0	225.8	0.5	<b>21.7</b>	<b>0.3</b>	-9.6/0.0/17.5/-100.0
rB11-010000	3/0/0	276.5	1.4	31.3	0.6	4.2/-7.1/-4.2/0.0
rB11-110001	3/0/0	190.7	<b>3.5</b>	<b>34.2</b>	<b>0.6</b>	8.1/-25.7/-31.9/-50.0
rB12-111111	0/2/1	87.5	43.6	630.9	27.1	2.7/6.0/-8.9/-88.2
rC10-001000	3/0/0	<b>152.1</b>	<b>0.3</b>	27.7	0.0	44.7/-33.3/0.7/0.0
rC10-100001	2/1/0	<b>496.0</b>	<b>5.8</b>	<b>119.8</b>	<b>1.1</b>	-17.7/-15.5/-15.3/-27.3
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>485.9</b>	<b>8.5</b>	<b>57.7</b>	<b>2.0</b>	-33.8/-40.0/-36.9/-60.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>487.0</b>	<b>3.3</b>	<b>136.1</b>	<b>21.1</b>	-68.8/-45.5/-49.8/-82.9
radiationm40-10-02	0/3/0	<b>5085.2</b>	<b>27.8</b>	<b>295.9</b>	<b>32.1</b>	-91.5/-41.7/-51.4/-72.0
rail01	3/0/0	33.1	<b>1563.6</b>	<b>18.6</b>	0.0	-6.3/-18.1/-36.0/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	1.2	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<b>37.5</b>	0.3	23.5	<b>0.8</b>	-55.7/0.0/-3.0/-62.5

(continued)

Table A.23 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
rd-rplusc-21	0/0/3	57.9	34.5	808.2	330.3	0.3/4.7/6.7/8.4
reblock115	3/0/0	<i>17.0</i>	<i>2.0</i>	<i>81.4</i>	<i>11.5</i>	-34.1/-20.0/-31.9/-46.1
rmatr100-p10	3/0/0	<b>3.0</b>	<i>0.9</i>	<b>5.3</b>	0.0	89.8/-33.3/-56.6/0.0
rmatr200-p5	3/0/0	<b>16.5</b>	<i>30.7</i>	<i>6.3</i>	0.0	15.4/-54.1/-68.3/0.0
rocl-4-11	0/0/3	74.5	<b>17.1</b>	793.6	102.2	-7.1/19.3/14.9/1.5
rocll-5-11	0/3/0	<b>63.9</b>	<i>20.1</i>	<i>401.0</i>	<i>143.1</i>	29.3/-58.2/-61.1/-63.2
roi2alpha3n4	3/0/0	<b>51.5</b>	<b>7.4</b>	<b>7.0</b>	<b>0.0</b>	17.5/77.8/79.6/100.0
roi5alpha10n8	3/0/0	56.6	<b>96.6</b>	<b>8.0</b>	0.0	5.8/78.4/72.4/0.0
roll3000	0/3/0	<i>67.3</i>	1.1	<i>56.4</i>	<i>6.2</i>	-61.1/0.0/-14.2/-27.4
rout	0/3/0	<b>44.4</b>	<b>0.1</b>	37.6	<i>3.2</i>	10.3/50.0/-6.4/-46.9
s100	3/0/0	1.7	276.6	6.0	0.0	0.0/8.6/9.1/0.0
s250r10	3/0/0	0.1	52.1	2.0	0.0	0.0/2.4/0.0/0.0
satellites2-40	0/3/0	<b>203.7</b>	<i>172.2</i>	<i>147.0</i>	<i>56.7</i>	17.0/-74.3/-76.3/-95.2
satellites2-60-fs	0/1/2	<i>350.9</i>	<i>286.9</i>	417.2	185.0	-74.5/-92.1/-91.6/-98.5
savshed1	0/3/0	<i>13.2</i>	<b>150.9</b>	<b>8.3</b>	0.0	-40.2/20.6/32.5/0.0
sct2	3/0/0	<i>42.8</i>	<b>0.2</b>	<b>6.7</b>	<b>0.0</b>	-31.8/66.7/74.3/100.0
set1ch	3/0/0	85.3	0.1	31.0	1.0	0.4/0.0/0.0/0.0
seymour	3/0/0	12.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<i>3.2</i>	<b>1.7</b>	<b>3.0</b>	0.0	-56.3/37.0/60.5/0.0
sing326	3/0/0	<i>63.4</i>	<b>12.9</b>	<b>8.6</b>	<b>0.0</b>	-83.3/47.8/74.7/100.0
sing44	3/0/0	<i>17.9</i>	<b>10.3</b>	<b>4.6</b>	<b>0.0</b>	-58.7/61.0/88.1/100.0
snp-02-004-104	0/3/0	<i>234.9</i>	<i>22.3</i>	33.3	<b>1.3</b>	-99.3/-11.7/0.9/31.6
sorrell3	3/0/0	76.3	0.9	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.7	<i>1.6</i>	0.0/0.0/-1.3/-18.8
sp97ar	3/0/0	25.7	0.9	2.2	0.0	3.4/0.0/0.0/0.0
sp98ar	3/0/0	24.1	0.6	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.0	<b>53.5</b>	<b>9.0</b>	0.0	-0.4/13.8/30.8/0.0
square41	0/3/0	6.7	<i>1820.4</i>	<i>13.5</i>	0.0	0.0/-32.9/-25.9/0.0
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>41.2</b>	<b>91.1</b>	<b>7.5</b>	0.0	75.8/17.3/44.9/0.0
supportcase12	0/3/0	<i>5.7</i>	<b>4.7</b>	<b>4.0</b>	0.0	-68.4/67.8/81.0/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>34.2</b>	0.2	<b>76.6</b>	<b>46.3</b>	99.6/0.0/14.6/26.9
supportcase33	0/3/0	61.5	<i>16.3</i>	<i>185.5</i>	<i>40.1</i>	4.7/-15.3/-34.6/-63.8
supportcase40	3/0/0	<i>120.7</i>	<b>1.8</b>	<b>8.0</b>	0.0	-85.4/57.1/51.8/0.0
supportcase42	0/3/0	<b>17.0</b>	4.0	<b>8.0</b>	0.0	30.3/4.8/31.0/0.0
supportcase6	3/0/0	0.4	<b>6.2</b>	<b>5.3</b>	0.0	0.0/53.4/55.8/0.0
supportcase7	3/0/0	15.1	<b>5.5</b>	<b>11.9</b>	0.0	-5.3/33.7/54.2/0.0
swath	0/2/1	<i>202.2</i>	<i>23.6</i>	303.5	106.2	-10.2/-42.8/-38.1/-43.9
swath1	3/0/0	<b>25.7</b>	<b>1.0</b>	<b>39.0</b>	<b>4.3</b>	57.5/56.5/37.3/72.6
swath3	3/0/0	<b>12.5</b>	<b>1.0</b>	<b>36.7</b>	3.3	62.3/33.3/14.5/-3.0
t1717	3/0/0	<b>149.3</b>	<b>104.3</b>	<i>51.6</i>	<i>0.6</i>	16.7/17.4/-15.7/-100.0
tbfp-network	3/0/0	<b>19.3</b>	<b>12.2</b>	12.9	0.0	90.3/45.5/7.9/0.0
thor50dday	3/0/0	<i>315.9</i>	<i>8.1</i>	26.7	<i>2.3</i>	-18.4/-11.1/-8.2/-26.1
timtab1	0/3/0	56.8	<i>0.9</i>	111.8	26.9	-2.3/-33.3/1.7/3.6
timtab2	0/0/3	<i>82.2</i>	<i>13.8</i>	1326.5	525.1	-10.5/-58.0/-40.3/-48.5
tr12-30	3/0/0	<b>49.0</b>	0.2	<i>35.3</i>	<i>5.1</i>	32.8/0.0/-10.2/-68.6
traininstance2	0/1/2	<b>70.5</b>	<i>4.6</i>	750.3	70.9	71.1/-28.3/-13.4/-3.2
traininstance6	0/3/0	<b>65.3</b>	<b>0.9</b>	226.1	33.6	85.9/25.0/26.1/20.2
trento1	3/0/0	203.5	<i>16.5</i>	<i>18.2</i>	0.0	-8.1/-51.5/-48.9/0.0
triptim1	0/3/0	0.1	21.6	3.6	0.0	0.0/7.3/10.0/0.0
uccase12	3/0/0	1.9	10.8	16.6	0.0	0.0/-4.6/-6.0/0.0
uccase9	3/0/0	<b>376.0</b>	<b>11.2</b>	27.5	2.8	93.3/80.7/85.5/96.2
uct-subprob	3/0/0	<i>18.8</i>	<b>0.5</b>	7.7	0.0	-34.0/16.7/0.0/0.0
unitcal-7	0/0/3	27.4	135.6	1016.6	109.6	-2.2/1.5/-2.5/24.9
var-smallemery-m6j6	3/0/0	<b>25.4</b>	<b>3.3</b>	<b>6.3</b>	<b>0.0</b>	90.1/86.2/90.7/100.0
vpm2	3/0/0	41.8	0.1	<i>27.2</i>	<i>0.3</i>	7.1/0.0/-25.0/-100.0
wachplan	0/3/0	0.0	<b>1.2</b>	<b>15.1</b>	0.0	0.0/60.0/43.0/0.0
Geom. means			(271 instances)	(227 instances)		
FP		45.7	5.4	15.7	1.1	

(continued)

Table A.23 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
FP+(3,1,h,c, $\Delta$ )		<b>42.7</b>	5.4	<b>12.8</b>	<b>0.9</b>	

Table A.24.: Performance of FP+(3,sv,g,c, $\Delta$ )

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	3/0/0	<b>1.1</b>	<b>2.5</b>	<b>47.2</b>	<b>0.0</b>	90.9/79.5/70.4/100.0
30n20b8	0/3/0	<b>389.3</b>	<b>9.8</b>	<b>365.6</b>	<b>79.7</b>	15.8/-41.8/-54.3/-63.7
50v-10	0/3/0	<b>139.7</b>	<b>0.2</b>	<b>19.3</b>	<b>0.0</b>	-10.7/33.3/16.1/100.0
CMS750-4	3/0/0	<b>70.0</b>	<b>5.7</b>	<b>93.9</b>	<b>19.0</b>	-24.3/-28.1/-30.7/-36.8
a1c1s1	3/0/0	<b>44.8</b>	<b>0.5</b>	31.3	1.3	15.2/-20.0/0.0/0.0
academictimetablesmall	0/0/1	inf	576.8	1103.0	0.0	-/-/-/-
aflow30a	3/0/0	<b>111.8</b>	0.1	34.0	<b>2.9</b>	15.0/0.0/-1.5/-31.0
aflow40b	3/0/0	<b>256.8</b>	<b>0.5</b>	<b>38.7</b>	<b>2.7</b>	-19.3/-40.0/-17.3/-44.4
air04	3/0/0	<b>4.4</b>	<b>4.1</b>	<b>30.9</b>	0.0	-97.7/-36.6/-78.6/0.0
air05	3/0/0	<b>2.4</b>	<b>0.9</b>	<b>5.0</b>	0.0	41.5/-11.1/-20.0/0.0
app1-1	3/0/0	<b>53.0</b>	<b>0.6</b>	<b>39.9</b>	3.6	-94.2/-16.7/-13.3/10.0
app1-2	3/0/0	43.9	<b>8.4</b>	<b>37.6</b>	<b>7.1</b>	0.0/21.5/27.4/53.6
arki001	0/2/1	3.0	<b>16.2</b>	837.1	210.3	-3.3/21.7/-3.9/-11.4
assign1-5-8	3/0/0	<b>5.0</b>	0.1	<b>5.3</b>	0.0	-62.0/0.0/76.2/0.0
atlanta-ip	2/1/0	<b>22.4</b>	<b>20.0</b>	<b>50.6</b>	<b>2.0</b>	-19.6/-15.5/-49.0/-70.0
b1c1s1	3/0/0	<b>211.1</b>	<b>0.6</b>	34.7	<b>4.3</b>	-23.6/-16.7/-2.9/-16.3
bab2	0/0/3	<b>16.3</b>	<b>788.0</b>	748.6	248.5	36.1/-60.1/-76.9/-90.5
bab6	0/2/1	<b>18.2</b>	<b>181.3</b>	270.5	37.1	23.2/-42.4/-67.6/-58.8
beasleyC3	3/0/0	10.9	0.2	35.7	<b>5.6</b>	6.0/0.0/-2.0/-14.3
binkar10-1	3/0/0	<b>1.7</b>	0.1	14.3	0.0	57.5/0.0/8.9/0.0
blp-ar98	3/0/0	73.9	1.8	<b>14.6</b>	0.0	-3.5/10.0/13.6/0.0
blp-ic98	3/0/0	36.3	0.4	2.2	0.0	2.7/0.0/0.0/0.0
bnatt400	0/0/1	0.0	282.2	1082.0	0.0	-/-/-/-
bppc4-08	3/0/0	54.5	<b>0.1</b>	<b>6.0</b>	<b>0.0</b>	-5.3/91.7/90.4/100.0
brazil3	0/3/0	<b>263.7</b>	<b>45.8</b>	<b>40.9</b>	0.0	58.4/-53.9/-47.7/0.0
buildingenergy	0/3/0	<b>0.9</b>	<b>176.8</b>	<b>4.0</b>	0.0	18.2/74.6/65.8/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.5	40.3	10.3	0.0/7.4/-0.7/-2.9
chromaticindex1024-7	3/0/0	0.0	<b>61.5</b>	<b>6.3</b>	0.0	0.0/-10.9/-52.4/0.0
chromaticindex512-7	3/0/0	0.0	<b>70.3</b>	<b>6.9</b>	0.0	0.0/-36.0/-71.0/0.0
cmflsp50-24-8-8	3/0/0	<b>15.0</b>	<b>17.5</b>	143.4	39.3	23.1/89.6/86.3/86.7
co-100	3/0/0	<b>377.5</b>	6.0	17.0	0.0	-19.8/1.6/-8.2/0.0
cod105	3/0/0	100.0	1.7	1.0	0.0	0.0/5.6/0.0/0.0
comp07-2idx	0/3/0	3110.3	<b>16.0</b>	<b>55.2</b>	<b>0.6</b>	9.2/-61.3/-56.5/-100.0
comp21-2idx	0/3/0	389.5	<b>14.1</b>	<b>64.3</b>	<b>1.0</b>	8.8/-67.4/-61.0/-100.0
cost266-UUE	3/0/0	35.6	<b>0.3</b>	<b>19.7</b>	<b>0.4</b>	-1.4/25.0/16.2/-25.0
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/0/3	<b>48.0</b>	<b>8.8</b>	984.9	340.2	30.4/-30.7/-61.2/-85.5
csched008	0/2/1	9.6	<b>3.1</b>	394.8	131.3	2.0/-45.2/-61.5/-81.7
cvs16r128-89	3/0/0	97.9	0.9	1.0	0.0	0.0/10.0/0.0/0.0
dano3-3	3/0/0	0.0	18.0	<b>2.0</b>	0.0	0.0/3.7/87.7/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>19.2</b>	<b>2.0</b>	<b>0.0</b>	-33.3/56.4/93.4/100.0
dano3mip	3/0/0	<b>15.4</b>	<b>23.8</b>	<b>5.0</b>	<b>0.0</b>	10.5/91.5/92.9/100.0
danoint	2/1/0	<b>59.0</b>	<b>1.0</b>	<b>60.6</b>	<b>11.9</b>	90.9/75.0/45.7/71.1
disctom	3/0/0	0.0	1.3	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>7.4</b>	<b>0.4</b>	<b>16.2</b>	0.0	-24.3/-25.0/-19.8/0.0
drayage-25-23	3/0/0	<b>6.7</b>	<b>0.2</b>	<b>5.0</b>	0.0	34.3/50.0/69.5/0.0
ds	3/0/0	4945.0	5.9	1.0	0.0	0.0/1.7/0.0/0.0
dws008-01	0/0/3	<b>63.7</b>	<b>88.0</b>	1124.7	373.2	33.6/-15.2/-27.1/-36.8
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	<b>0.9</b>	1.0	0.0	0.0/18.2/0.0/0.0
enlight-hard	0/0/2	0.0	3.7	877.9	242.6	-/-/-/-
exp-1-500-5-5	3/0/0	<b>120.1</b>	0.1	<b>23.4</b>	0.0	-37.2/0.0/13.0/0.0

(continued)

Table A.24 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
fast0507	3/0/0	25.0	0.9	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>814.9</b>	<i>0.7</i>	<i>42.3</i>	<i>1.6</i>	10.2/-42.9/-52.0/-100.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>13.8</b>	<b>1.5</b>	<b>9.0</b>	<b>0.0</b>	19.8/78.6/83.9/100.0
fiber	3/0/0	<b>107.5</b>	0.1	15.0	0.0	30.0/0.0/-0.7/0.0
fixnet6	3/0/0	<i>58.8</i>	0.1	31.0	1.0	-27.6/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<i>12.7</i>	0.1	3.1	0.0	-17.3/0.0/-6.5/0.0
germanrr	0/3/0	4.5	<i>13.4</i>	<i>83.7</i>	<i>13.8</i>	-8.9/-12.7/-39.3/-57.2
gesa2	0/3/0	2.6	0.2	20.4	0.0	-7.7/0.0/0.0/0.0
gesa2-o	0/3/0	<b>17.4</b>	0.2	34.8	<b>1.3</b>	13.0/0.0/2.2/13.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	<b>0.5</b>	1.0	0.0	0.0/16.7/0.0/0.0
glass4	3/0/0	<b>187.7</b>	<b>0.1</b>	<b>56.1</b>	<b>17.5</b>	72.5/66.7/46.2/45.7
gmu-35-40	3/0/0	<i>7.4</i>	0.1	<b>3.0</b>	0.0	-12.2/0.0/78.6/0.0
gmu-35-50	3/0/0	12.4	0.3	<b>23.4</b>	<i>2.8</i>	-1.6/0.0/25.5/-64.3
graph20-20-1rand	3/0/0	<i>16.1</i>	<b>2.5</b>	<b>27.3</b>	<b>0.0</b>	-13.0/39.0/12.8/100.0
graphdraw-domain	0/3/0	<i>58.5</i>	<b>0.1</b>	<b>13.2</b>	<b>0.0</b>	-50.8/66.7/78.3/100.0
h80x6320d	3/0/0	22.5	1.2	32.0	1.9	-2.2/0.0/0.0/0.0
harp2	3/0/0	11.3	0.1	12.7	0.0	8.9/0.0/0.0/0.0
highschool1-aigio	0/3/0	inf	<i>1267.2</i>	<i>52.5</i>	0.0	0.0/-45.7/-70.9/0.0
hypothyroid-k1	3/0/0	0.0	5.0	1.0	0.0	0.0/-4.0/0.0/0.0
ic97p	0/3/0	<b>11.2</b>	<b>0.8</b>	134.1	44.5	27.3/84.3/84.9/78.3
ic97t	0/0/3	12.2	<i>4.4</i>	1561.5	569.0	1.6/-11.4/-18.9/-45.3
icir97p	0/0/3	<b>20.2</b>	23.3	936.6	241.8	11.8/-7.3/17.8/-10.8
icir97t	0/3/0	15.5	<i>15.3</i>	<i>524.1</i>	<i>314.9</i>	1.3/-71.2/-59.8/-59.1
irish-electricity	3/0/0	<i>7.5</i>	<b>10.8</b>	<b>8.4</b>	<b>0.0</b>	-20.0/44.3/65.3/100.0
irp	3/0/0	<b>2.5</b>	0.3	<b>3.0</b>	0.0	34.2/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>18.8</b>	<b>4.1</b>	<b>13.6</b>	0.0	47.8/35.9/38.2/0.0
k1mushroom	3/0/0	18.2	40.4	1.0	0.0	0.0/-1.5/0.0/0.0
lectsched-5-obj	0/0/3	<i>2572.6</i>	<i>145.1</i>	1505.7	2.7	-12.7/-42.1/-39.7/61.4
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>407.2</b>	<b>0.2</b>	<b>13.6</b>	<b>0.0</b>	39.6/81.8/84.9/100.0
lotsize	3/0/0	<i>215.9</i>	0.5	47.3	<i>12.3</i>	-67.3/0.0/-5.1/-14.6
mad	3/0/0	<b>6322.9</b>	0.1	15.5	0.0	48.8/0.0/-5.2/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<i>63.5</i>	<b>13.0</b>	<b>7.7</b>	<b>0.0</b>	-29.6/73.9/78.5/100.0
map16715-04	3/0/0	<b>70.4</b>	<b>17.5</b>	<b>8.3</b>	<b>0.0</b>	21.1/69.2/82.1/100.0
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>41.0</b>	<b>0.1</b>	<b>8.6</b>	<b>0.0</b>	91.4/50.0/90.4/100.0
mas76	0/3/0	<b>12.2</b>	<b>0.1</b>	<b>5.3</b>	<b>0.0</b>	88.5/50.0/94.2/100.0
mc11	3/0/0	114.5	0.4	43.3	13.3	-5.5/0.0/-1.6/-7.5
mcsched	3/0/0	<i>21.2</i>	0.5	<i>4.6</i>	0.0	-39.2/0.0/-21.7/0.0
mik-250-20-75-4	0/3/0	<b>16.5</b>	<b>0.1</b>	<b>6.9</b>	<b>0.0</b>	73.0/50.0/82.0/100.0
milo-v12-6-r2-40-1	3/0/0	<b>125.9</b>	<b>0.8</b>	42.3	12.3	16.2/11.1/-0.7/-2.4
misc07	3/0/0	<b>14.4</b>	0.1	<i>26.1</i>	<i>0.3</i>	49.7/0.0/-23.0/-100.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>4.3</b>	<b>0.1</b>	<b>6.6</b>	0.0	69.3/66.7/66.3/0.0
modglob	3/0/0	<b>50.8</b>	0.1	<b>6.0</b>	<b>0.0</b>	52.0/0.0/80.8/100.0
momentum1	0/1/2	<b>169.3</b>	<i>74.3</i>	1083.0	558.8	12.5/-46.8/-48.5/-36.8
msc98-ip	3/0/0	<b>12.5</b>	5.7	31.7	<i>1.0</i>	19.4/9.5/-3.2/-40.0
mushroom-best	0/3/0	8.35e06	<i>25.1</i>	<i>61.3</i>	<b>0.3</b>	8.9/-45.8/-34.7/82.4
mzzv11	0/3/0	<i>25.1</i>	<b>3.1</b>	18.1	0.0	-19.9/26.2/6.2/0.0
mzzv42z	0/3/0	<b>26.6</b>	<b>1.7</b>	<b>7.0</b>	<b>0.0</b>	14.2/65.3/70.6/100.0
n2seq36q	3/0/0	29.9	<b>0.3</b>	1.0	0.0	0.0/25.0/0.0/0.0
n3div36	3/0/0	39.2	<b>0.3</b>	1.0	0.0	0.0/25.0/0.0/0.0
n5-3	0/3/0	9.4	0.3	<i>27.2</i>	<i>0.3</i>	0.0/0.0/-25.0/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.24 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-1171448	3/0/0	<b>16.9</b>	<b>1.1</b>	<b>4.6</b>	<b>0.0</b>	-94.7/77.6/82.6/100.0
neos-1171737	3/0/0	<b>11.8</b>	<b>0.4</b>	<b>4.6</b>	<b>0.0</b>	-66.9/75.0/84.5/100.0
neos-1354092	0/3/0	<b>10.7</b>	<b>91.4</b>	<b>23.2</b>	0.0	40.9/48.2/38.3/0.0
neos-1445765	3/0/0	36.8	<b>0.6</b>	6.0	0.0	-3.8/25.0/-6.7/0.0
neos-1456979	0/2/1	<b>127.1</b>	<b>34.7</b>	462.0	81.4	15.2/14.1/0.1/15.6
neos-1582420	0/3/0	<b>99.7</b>	<b>4.7</b>	<b>328.8</b>	<b>75.1</b>	-30.8/-68.1/-75.8/-87.5
neos-2657525-crna	0/3/0	961.7	0.2	<b>48.7</b>	1.9	5.4/0.0/-14.2/5.0
neos-2746589-doon	0/0/3	<b>8.0</b>	<b>537.1</b>	711.3	28.4	77.1/-74.3/-65.1/9.3
neos-2978193-inde	3/0/0	<b>3.9</b>	0.2	<b>3.6</b>	0.0	-15.4/0.0/-36.1/0.0
neos-2987310-joes	2/1/0	<b>0.9</b>	9.5	59.0	<b>13.2</b>	-66.7/0.0/-8.0/10.8
neos-3004026-krka	0/0/3	0.0	<b>163.2</b>	1886.1	4.5	0.0/-33.2/-31.8/-20.0
neos-3024952-loue	0/0/3	<b>904.5</b>	<b>175.9</b>	1375.4	0.0	-10.1/-54.6/2.7/100.0
neos-3046615-murg	0/3/0	<b>14.0</b>	<b>0.1</b>	84.9	<b>53.4</b>	99.9/50.0/10.0/18.6
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/1/2	129.2	<b>144.0</b>	778.8	110.9	-6.4/68.6/29.0/-100.0
neos-3381206-awhea	0/0/3	4.9	18.9	784.4	0.4	0.0/-3.2/25.6/63.6
neos-3402294-bobin	3/0/0	<b>332.4</b>	<b>24.7</b>	<b>23.0</b>	0.0	22.6/-18.6/-17.0/0.0
neos-3555904-turama	3/0/0	<b>4.3</b>	<b>102.0</b>	<b>37.5</b>	<b>0.0</b>	-53.5/-23.3/-16.3/100.0
neos-3627168-kasai	3/0/0	<b>1.1</b>	0.1	22.0	<b>0.3</b>	26.7/0.0/-7.3/-100.0
neos-3656078-kumeu	0/0/3	27.8	<b>112.3</b>	846.3	0.0	9.7/20.0/18.7/100.0
neos-3754480-nidda	3/0/0	<b>2.13e05</b>	<b>0.1</b>	<b>15.8</b>	<b>0.0</b>	-99.8/50.0/76.7/100.0
neos-4300652-rahue	0/0/3	279.3	<b>668.4</b>	1053.3	3.8	-4.8/-38.2/-66.3/-92.1
neos-4338804-snowy	0/3/0	<b>3125.4</b>	<b>0.6</b>	<b>82.6</b>	<b>23.7</b>	97.3/25.0/17.8/15.4
neos-4387871-tavua	0/2/1	<b>893.0</b>	<b>15.5</b>	713.8	359.3	-15.5/32.3/11.0/15.9
neos-4413714-turia	3/0/0	<b>87.1</b>	<b>18.1</b>	<b>7.0</b>	<b>0.0</b>	-49.6/77.3/91.2/100.0
neos-4532248-waihi	0/1/2	949.4	<b>597.2</b>	804.7	115.2	0.0/-18.1/-45.4/-68.7
neos-4647030-tutaki	3/0/0	<b>40.3</b>	15.9	<b>20.4</b>	0.0	-45.4/9.1/-13.2/0.0
neos-4722843-widden	0/3/0	<b>63.9</b>	<b>46.4</b>	<b>80.0</b>	<b>17.5</b>	67.7/15.8/13.4/31.6
neos-4738912-atrato	0/3/0	<b>7.4</b>	0.3	<b>14.3</b>	0.0	38.3/0.0/-13.3/0.0
neos-4763324-toguru	3/0/0	59.2	<b>17.2</b>	<b>10.7</b>	0.0	0.0/18.5/54.9/0.0
neos-4954672-berkel	3/0/0	<b>74.7</b>	0.1	<b>14.6</b>	<b>0.0</b>	-26.8/0.0/54.4/100.0
neos-5049753-cuanza	0/2/1	<b>44.1</b>	<b>940.1</b>	421.9	114.1	41.7/-18.1/-22.8/-36.9
neos-5052403-cygnat	3/0/0	<b>1.0</b>	42.3	2.3	0.0	23.1/-0.5/0.0/0.0
neos-5093327-huahum	3/0/0	<b>27.2</b>	<b>4.9</b>	<b>55.2</b>	<b>21.8</b>	97.0/63.4/54.3/74.8
neos-5104907-jarama	0/0/2	144.2	1797.7	758.0	235.1	-/-/-/-
neos-5107597-kakapo	3/0/0	37182.6	1.7	<b>139.3</b>	<b>106.1</b>	5.4/5.6/-11.5/-10.6
neos-5114902-kasavu	2/1/0	31.6	1907.4	105.9	24.2	-/-/-/-
neos-5188808-nattai	3/0/0	<b>4656.3</b>	<b>3.8</b>	<b>18.5</b>	0.0	-13.8/33.3/30.7/0.0
neos-5195221-niemur	3/0/0	<b>589.6</b>	<b>11.1</b>	<b>21.8</b>	0.0	23.2/-33.3/-14.2/0.0
neos-631710	3/0/0	149.4	2.6	1.0	0.0	0.0/-3.8/0.0/0.0
neos-662469	0/3/0	<b>329.3</b>	<b>3.5</b>	<b>10.3</b>	<b>0.0</b>	-32.3/45.3/46.6/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	<b>0.4</b>	0.0	0.0	0.0/20.0/0.0/0.0
neos-848589	3/0/0	<b>1.50e05</b>	<b>120.5</b>	<b>89.3</b>	<b>28.7</b>	49.3/-14.3/-22.4/-27.9
neos-860300	3/0/0	62.1	<b>1.4</b>	<b>18.5</b>	0.0	-8.2/-71.4/-78.4/0.0
neos-873061	3/0/0	57.3	<b>23.1</b>	31.3	<b>1.3</b>	6.4/10.1/1.3/18.8
neos-911970	3/0/0	<b>221.2</b>	<b>0.1</b>	<b>18.2</b>	<b>0.0</b>	-40.3/50.0/63.6/100.0
neos-933966	3/0/0	<b>19.5</b>	<b>4.5</b>	10.1	0.0	91.3/-64.4/-6.9/0.0
neos-950242	3/0/0	<b>105.5</b>	<b>11.3</b>	<b>38.0</b>	<b>1.6</b>	17.8/-40.7/-42.6/-75.0
neos-957323	3/0/0	6.6	2.1	1.9	0.0	0.0/0.0/0.0/0.0
neos-960392	1/2/0	2.3	<b>28.1</b>	<b>115.8</b>	<b>2.8</b>	0.0/-28.1/-46.5/-25.0
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<b>2.4</b>	<b>7.6</b>	975.3	6.9	-41.7/18.3/16.5/-62.3
neos17	3/0/0	309.3	0.2	34.9	<b>2.7</b>	-6.2/0.0/-9.2/-40.7
neos20	0/0/3	<b>64.7</b>	9.5	1172.7	85.7	-29.4/3.1/0.8/-5.0
neos5	3/0/0	<b>49.7</b>	0.1	<b>2.9</b>	0.0	-16.3/0.0/23.7/0.0
neos7	0/3/0	<b>13.0</b>	<b>0.1</b>	<b>4.6</b>	0.0	-15.4/50.0/81.6/0.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>6.4</b>	<b>4.8</b>	26.8	0.0	83.3/-10.4/-4.1/0.0
netdiversion	3/0/0	80.2	<b>164.3</b>	<b>10.9</b>	0.0	7.2/-54.4/-11.9/0.0
nexp-150-20-8-5	3/0/0	145.9	<b>0.3</b>	<b>3.0</b>	0.0	0.0/40.0/57.1/0.0

(continued)

Table A.24 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
nh97p	0/0/3	10.7	13.5	935.9	281.2	-4.7/0.7/14.3/-7.9
nh97t	0/1/2	<b>8.3</b>	<b>10.7</b>	790.0	250.4	21.7/16.4/27.6/23.3
noswot	0/3/0	<b>2.6</b>	0.1	<b>11.5</b>	1.4	72.9/0.0/66.5/-7.1
ns1116954	0/0/3	0.0	<b>1018.4</b>	1345.3	14.2	0.0/-53.7/-65.3/-77.5
ns1208400	2/1/0	0.0	<b>17.9</b>	<b>104.7</b>	<b>0.7</b>	0.0/80.1/73.5/-57.1
ns1644855	3/0/0	<b>21.6</b>	<b>218.4</b>	<b>5.0</b>	<b>0.0</b>	-97.7/44.1/85.5/100.0
ns1760995	3/0/0	<b>49.5</b>	<b>14.8</b>	<b>12.3</b>	<b>0.0</b>	-69.9/82.5/84.7/100.0
ns1830653	2/0/1	<b>522.1</b>	<b>10.7</b>	268.3	5.5	-68.6/-58.9/-78.1/-81.8
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-idx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.3	<b>0.1</b>	<b>3.0</b>	0.0	0.0/66.7/84.2/0.0
nursesched-medium-hint03	0/3/0	<b>1281.3</b>	<b>85.0</b>	<b>51.2</b>	<b>1.9</b>	-38.6/-83.6/-77.7/-100.0
nursesched-sprint02	0/3/0	<b>46.1</b>	<b>2.7</b>	<b>14.9</b>	0.0	16.5/-29.6/-37.6/0.0
nw04	3/0/0	3.9	<b>1.3</b>	<b>4.9</b>	0.0	0.0/35.0/38.7/0.0
opm2-z10-s4	3/0/0	94.2	27.0	1.0	0.0	0.0/1.1/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	0.1	<b>5.6</b>	<b>0.0</b>	100.0/0.0/84.6/100.0
p200x1188c	3/0/0	3.9	0.2	31.0	1.0	0.0/0.0/0.0/0.0
p2756	0/3/0	75.2	0.1	5.0	0.0	8.4/0.0/0.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/-
pg	3/0/0	<b>4.6</b>	<b>0.1</b>	<b>10.9</b>	<b>0.0</b>	70.3/66.7/78.9/100.0
pg5-34	3/0/0	7.6	<b>0.1</b>	<b>7.4</b>	<b>0.0</b>	-6.6/75.0/85.8/100.0
physiciansched3-3	1/1/1	<b>561.7</b>	<b>68.8</b>	295.0	41.7	-98.5/-20.8/-84.4/-97.6
physiciansched6-2	0/0/3	<b>3.8</b>	<b>53.7</b>	755.0	63.2	22.4/36.4/-2.0/-44.9
piperout-08	0/0/3	<b>79.3</b>	<b>57.7</b>	1354.2	27.1	79.9/16.6/20.8/18.6
piperout-27	0/0/3	<b>92.0</b>	<b>50.6</b>	934.1	16.5	59.7/23.3/22.0/6.3
pk1	3/0/0	<b>279.9</b>	<b>0.1</b>	<b>33.6</b>	<b>0.6</b>	76.5/50.0/42.1/93.3
pp08a	3/0/0	<b>65.4</b>	0.1	16.4	0.0	-10.7/0.0/-4.9/0.0
pp08aCUTS	3/0/0	<b>26.1</b>	0.1	<b>10.5</b>	0.0	25.6/0.0/12.5/0.0
proteindesign121hz512p9	0/3/0	<b>10.8</b>	<b>73.7</b>	<b>336.8</b>	<b>21.4</b>	-77.8/-93.2/-92.8/-98.6
proteindesign122trx11p8	0/2/1	<b>2.9</b>	<b>33.1</b>	155.8	8.4	-62.1/-97.0/-97.4/-100.0
protfold	1/2/0	67.6	<b>14.2</b>	<b>159.6</b>	<b>12.3</b>	-2.4/-40.8/-76.3/-100.0
qap10	3/0/0	19.4	<b>17.1</b>	<b>4.0</b>	0.0	0.0/-19.9/-50.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	<b>319.8</b>	0.5	23.0	<b>0.3</b>	-24.9/0.0/9.1/-100.0
rB10-011001	3/0/0	<b>229.0</b>	0.5	<b>22.7</b>	0.0	-10.9/0.0/13.7/0.0
rB11-010000	3/0/0	<b>385.7</b>	1.3	<b>24.0</b>	<b>0.0</b>	-25.1/0.0/20.0/100.0
rB11-110001	3/0/0	<b>247.1</b>	2.7	22.5	0.3	-16.0/-3.7/3.4/0.0
rB12-111111	1/2/0	<b>76.0</b>	<b>25.1</b>	359.3	42.4	15.5/45.9/37.5/-92.5
rC10-001000	3/0/0	<b>169.0</b>	<b>0.3</b>	<b>33.0</b>	0.0	38.6/-33.3/-15.5/0.0
rC10-100001	3/0/0	397.2	<b>4.1</b>	96.8	0.8	2.7/16.3/4.6/0.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	333.8	<b>7.3</b>	<b>59.3</b>	<b>2.0</b>	-3.6/-30.1/-38.6/-60.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>411.1</b>	<b>2.6</b>	<b>114.2</b>	<b>14.8</b>	-63.0/-30.8/-40.2/-75.7
radiationm40-10-02	0/3/0	<b>5127.9</b>	<b>28.4</b>	<b>309.4</b>	<b>39.5</b>	-91.6/-43.0/-53.5/-77.2
rail01	2/1/0	<b>35.8</b>	<b>2274.8</b>	<b>34.8</b>	0.0	-13.4/-43.7/-65.8/0.0
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	<b>1.0</b>	1.0	0.0	0.0/16.7/0.0/0.0
ran14x18-disj-8	3/0/0	<b>37.5</b>	0.3	23.5	<b>0.8</b>	-55.7/0.0/-3.0/-62.5
rd-rplusc-21	0/0/3	56.7	34.0	916.7	375.2	2.4/6.1/-5.5/-3.9
reblock115	3/0/0	<b>9.2</b>	<b>1.2</b>	50.9	<b>3.4</b>	17.9/25.0/8.1/45.2
rmatr100-p10	3/0/0	<b>3.1</b>	<b>0.8</b>	<b>5.3</b>	0.0	89.5/-25.0/-56.6/0.0
rmatr200-p5	3/0/0	<b>16.5</b>	<b>28.4</b>	<b>6.6</b>	0.0	15.4/-50.4/-69.7/0.0
rocl-4-11	0/0/3	65.2	19.1	970.0	219.4	5.8/9.9/-3.9/-52.7
rocll-5-11	0/1/2	<b>79.5</b>	<b>39.3</b>	815.5	294.0	12.1/-78.6/-80.9/-82.1
roi2alpha3n4	3/0/0	<b>49.7</b>	<b>7.4</b>	<b>7.0</b>	<b>0.0</b>	20.4/77.8/79.6/100.0
roi5alpha10n8	3/0/0	56.6	<b>104.0</b>	<b>8.0</b>	0.0	5.8/76.7/72.4/0.0
roll3000	0/3/0	<b>29.3</b>	<b>0.6</b>	<b>25.2</b>	<b>1.4</b>	-10.6/45.5/47.9/68.9
rout	0/3/0	<b>41.5</b>	0.2	<b>41.5</b>	<b>3.8</b>	16.2/0.0/-15.2/-55.3
s100	3/0/0	<b>11.4</b>	<b>360.9</b>	<b>10.6</b>	0.0	-85.1/-16.1/-37.7/0.0

(continued)

Table A.24 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
s250r10	3/0/0	0.1	54.2	2.0	0.0	0.0/-1.5/0.0/0.0
satellites2-40	0/3/0	<b>135.9</b>	<b>221.0</b>	<b>147.0</b>	<b>57.0</b>	44.6/-80.0/-76.3/-95.3
satellites2-60-fs	0/1/2	<b>330.2</b>	<b>262.5</b>	417.2	186.3	-72.9/-91.4/-91.6/-98.6
savsched1	0/3/0	<b>12.5</b>	<b>144.1</b>	<b>8.3</b>	0.0	-36.8/24.2/32.5/0.0
sct2	3/0/0	<b>37.4</b>	<b>0.2</b>	<b>8.0</b>	<b>0.0</b>	-21.9/66.7/69.3/100.0
set1ch	3/0/0	<b>72.5</b>	0.1	31.0	1.0	15.3/0.0/0.0/0.0
seymour	3/0/0	12.7	<b>0.6</b>	1.0	0.0	0.0/14.3/0.0/0.0
seymour1	3/0/0	<b>2.9</b>	<b>1.7</b>	<b>3.3</b>	0.0	-51.7/37.0/56.6/0.0
sing326	3/0/0	<b>63.5</b>	<b>12.9</b>	<b>8.8</b>	<b>0.0</b>	-83.3/47.8/74.1/100.0
sing44	3/0/0	<b>17.9</b>	<b>10.5</b>	<b>4.6</b>	<b>0.0</b>	-58.7/60.2/88.1/100.0
snp-02-004-104	0/3/0	<b>226.0</b>	<b>23.6</b>	33.3	<b>1.3</b>	-99.2/-16.5/0.9/31.6
sorrell3	3/0/0	76.3	<b>0.8</b>	1.0	0.0	0.0/11.1/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.3	1.3	0.0/0.0/0.0/0.0
sp97ar	3/0/0	25.7	<b>0.8</b>	2.2	0.0	3.4/11.1/0.0/0.0
sp98ar	3/0/0	24.1	<b>0.5</b>	1.0	0.0	0.0/16.7/0.0/0.0
ssplice1k1	3/0/0	99.0	56.9	<b>9.0</b>	0.0	-0.4/8.4/30.8/0.0
square41	0/0/0	-	-	-	-	-/-/-/-
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>20.7</b>	110.2	<b>11.3</b>	0.0	87.8/-0.1/16.9/0.0
supportcase12	0/3/0	<b>5.5</b>	<b>4.8</b>	<b>4.3</b>	0.0	-67.3/67.1/79.5/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>29.3</b>	0.2	<b>75.0</b>	<b>44.3</b>	99.7/0.0/16.4/30.0
supportcase33	0/3/0	60.7	<b>19.8</b>	<b>247.7</b>	<b>53.8</b>	5.9/-30.3/-51.0/-73.0
supportcase40	3/0/0	<b>48.7</b>	<b>1.6</b>	<b>8.0</b>	0.0	-63.9/61.9/51.8/0.0
supportcase42	0/3/0	<b>17.2</b>	<b>5.1</b>	<b>9.8</b>	0.0	29.5/-17.6/15.5/0.0
supportcase6	3/0/0	0.4	<b>6.4</b>	<b>6.1</b>	0.0	0.0/51.9/49.2/0.0
supportcase7	3/0/0	15.1	<b>4.9</b>	<b>11.9</b>	0.0	-5.3/41.0/54.2/0.0
swath	0/2/1	<b>129.6</b>	<b>29.0</b>	335.0	123.4	28.6/-53.4/-43.9/-51.7
swath1	3/0/0	<b>12.0</b>	<b>1.8</b>	61.6	<b>14.1</b>	80.1/21.7/1.0/10.2
swath3	3/0/0	<b>18.0</b>	1.4	42.4	<b>5.5</b>	45.8/6.7/1.2/-41.8
t1717	3/0/0	<b>58.7</b>	131.2	<b>55.3</b>	<b>0.3</b>	67.2/-3.7/-21.3/-100.0
tbfp-network	3/0/0	<b>9.7</b>	<b>11.6</b>	13.4	0.0	95.1/48.2/4.3/0.0
thor50dday	3/0/0	<b>300.0</b>	7.7	25.8	<b>1.9</b>	-14.1/-6.5/-5.0/-10.5
timtab1	0/3/0	<b>65.3</b>	<b>0.7</b>	122.6	<b>42.3</b>	-15.0/-14.3/-7.3/-34.0
timtab2	0/1/2	77.3	<b>8.0</b>	883.8	359.6	-4.8/-27.5/-10.5/-24.8
tr12-30	3/0/0	<b>35.6</b>	<b>0.1</b>	33.2	<b>2.6</b>	51.2/50.0/-4.5/-38.5
traininstance2	0/0/3	<b>133.8</b>	<b>6.0</b>	1031.9	210.4	45.1/-45.0/-37.0/-67.4
traininstance6	0/2/1	<b>293.5</b>	<b>1.0</b>	235.8	44.9	36.4/16.7/22.9/-6.2
trento1	3/0/0	<b>13.4</b>	<b>16.2</b>	<b>16.5</b>	0.0	92.8/-50.6/-43.6/0.0
triptim1	0/3/0	0.1	<b>19.6</b>	3.6	0.0	0.0/15.9/10.0/0.0
uccase12	3/0/0	1.9	9.7	16.6	0.0	0.0/5.8/-6.0/0.0
uccase9	3/0/0	<b>387.8</b>	<b>11.2</b>	27.5	2.8	93.1/80.7/85.5/96.2
uct-subprob	3/0/0	<b>17.4</b>	<b>0.4</b>	7.7	0.0	-28.7/33.3/0.0/0.0
unitcal-7	0/0/3	25.6	133.8	972.4	132.4	4.5/2.8/1.9/9.3
var-smallemary-m6j6	3/0/0	<b>23.1</b>	<b>3.1</b>	<b>6.3</b>	<b>0.0</b>	91.0/87.1/90.7/100.0
vpm2	3/0/0	46.7	0.1	20.4	0.0	-3.6/0.0/0.0/0.0
wachplan	0/3/0	0.0	<b>1.8</b>	<b>18.9</b>	0.0	0.0/40.0/28.7/0.0
Geom. means			(270 instances)	(225 instances)		
FP		46.0	5.3	15.7	1.1	
FP+(3,sv,g,c, $\Delta$ )		<b>41.4</b>	<b>5.1</b>	<b>12.5</b>	<b>0.8</b>	

Table A.25.: Performance of FP+(3,sv,h,c, $\Delta$ )

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	1/2/0	<b>2.2</b>	<b>5.7</b>	<b>113.9</b>	<b>2.3</b>	81.8/53.3/28.6/-47.8
30n20b8	0/2/1	<b>359.3</b>	<b>12.6</b>	468.1	95.0	22.3/-54.8/-64.3/-69.6
50v-10	0/3/0	<b>146.5</b>	0.3	22.0	0.3	-14.9/0.0/4.3/0.0

(continued)



Table A.25 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
CMS750-4	3/0/0	<b>68.1</b>	<b>5.3</b>	<b>90.7</b>	<b>16.9</b>	-22.2/-22.6/-28.2/-29.0
a1c1s1	3/0/0	<b>39.0</b>	<b>0.5</b>	31.3	1.3	26.1/-20.0/0.0/0.0
academictimetables	0/0/2	inf	551.7	1441.7	13.3	-/-/-/-
aflow30a	3/0/0	<b>108.8</b>	0.1	34.0	<b>2.9</b>	17.3/0.0/-1.5/-31.0
aflow40b	3/0/0	221.7	0.3	32.8	1.6	-6.5/0.0/-2.4/-6.3
air04	3/0/0	<b>3.5</b>	<b>4.0</b>	<b>31.6</b>	<b>0.4</b>	-97.1/-35.0/-79.1/-100.0
air05	3/0/0	<b>2.5</b>	<b>0.6</b>	4.0	0.0	39.0/25.0/0.0/0.0
app1-1	3/0/0	<b>66.7</b>	<b>0.6</b>	<b>42.8</b>	<b>4.5</b>	-95.4/-16.7/-19.2/-11.1
app1-2	3/0/0	43.9	<b>7.9</b>	<b>37.3</b>	<b>6.7</b>	0.0/26.2/28.0/56.2
arki001	0/3/0	3.1	<b>15.0</b>	760.7	185.2	-6.5/27.5/5.4/0.6
assign1-5-8	3/0/0	<b>6.3</b>	0.1	<b>5.6</b>	0.0	-69.8/0.0/74.9/0.0
atlanta-ip	2/1/0	17.4	17.7	<b>30.8</b>	<b>1.6</b>	3.3/-4.5/-16.2/-62.5
b1c1s1	3/0/0	<b>133.9</b>	<b>0.6</b>	35.0	<b>4.3</b>	17.0/-16.7/-3.7/-16.3
bab2	1/0/2	<b>12.8</b>	<b>437.9</b>	302.7	28.7	49.8/-28.3/-42.8/-18.1
bab6	1/1/1	<b>13.8</b>	<b>164.7</b>	211.2	23.0	41.8/-36.6/-58.5/-33.5
beasleyC3	3/0/0	10.8	0.2	35.7	<b>5.6</b>	6.9/0.0/-2.0/-14.3
binkar10-1	3/0/0	<b>1.7</b>	0.1	14.3	0.0	57.5/0.0/8.9/0.0
blp-ar98	3/0/0	72.9	1.9	15.8	0.0	-2.2/5.0/6.5/0.0
blp-ic98	3/0/0	36.3	0.4	2.2	0.0	2.7/0.0/0.0/0.0
bnatt400	0/0/1	0.0	117.9	706.0	0.0	-/-/-/-
bppc4-08	3/0/0	54.5	<b>0.2</b>	<b>5.3</b>	<b>0.0</b>	-5.3/83.3/91.5/100.0
brazil3	0/3/0	<b>379.4</b>	<b>47.5</b>	<b>49.3</b>	0.0	40.2/-55.6/-56.6/0.0
buildingenergy	0/3/0	<b>0.9</b>	<b>165.3</b>	<b>4.0</b>	0.0	18.2/76.3/65.8/0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	0.0	2.6	41.3	<b>11.3</b>	0.0/3.7/-3.1/-11.5
chromaticindex1024-7	3/0/0	0.0	<b>63.2</b>	<b>6.3</b>	0.0	0.0/-13.3/-52.4/0.0
chromaticindex512-7	3/0/0	0.0	<b>69.4</b>	<b>7.1</b>	0.0	0.0/-35.2/-71.8/0.0
cmflsp50-24-8-8	2/1/0	<b>16.2</b>	<b>23.8</b>	189.0	52.6	16.9/85.8/82.0/82.1
co-100	3/0/0	<b>377.5</b>	5.6	17.0	0.0	-19.8/8.2/-8.2/0.0
cod105	3/0/0	100.0	<b>1.6</b>	1.0	0.0	0.0/11.1/0.0/0.0
comp07-2idx	0/3/0	3196.0	<b>15.6</b>	<b>57.9</b>	<b>0.6</b>	6.7/-60.3/-58.5/-100.0
comp21-2idx	0/3/0	<b>873.7</b>	<b>13.7</b>	<b>67.2</b>	<b>1.1</b>	-51.1/-66.4/-62.6/-100.0
cost266-UUE	3/0/0	36.7	<b>0.3</b>	<b>19.7</b>	<b>0.4</b>	-4.4/25.0/16.2/-25.0
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/0/3	<b>53.3</b>	<b>14.1</b>	1344.4	404.0	22.8/-56.7/-71.5/-87.8
csched008	1/1/1	9.2	<b>4.2</b>	472.6	148.3	6.1/-59.5/-67.8/-83.8
cvs16r128-89	3/0/0	97.9	0.9	1.0	0.0	0.0/10.0/0.0/0.0
dano3-3	3/0/0	0.0	19.5	<b>2.0</b>	0.0	0.0/-4.1/87.7/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>20.7</b>	<b>2.0</b>	<b>0.0</b>	-33.3/53.0/93.4/100.0
dano3mip	3/0/0	<b>15.4</b>	<b>23.3</b>	<b>5.0</b>	<b>0.0</b>	10.5/91.7/92.9/100.0
danooint	3/0/0	<b>59.0</b>	<b>1.1</b>	<b>62.3</b>	<b>14.2</b>	90.9/72.5/44.1/65.5
disctom	3/0/0	0.0	1.2	2.0	0.0	0.0/7.7/0.0/0.0
drayage-100-23	3/0/0	<b>24.1</b>	<b>0.5</b>	<b>18.1</b>	0.0	-76.8/-40.0/-28.2/0.0
drayage-25-23	3/0/0	<b>6.7</b>	<b>0.2</b>	<b>5.0</b>	0.0	34.3/50.0/69.5/0.0
ds	3/0/0	4945.0	5.4	1.0	0.0	0.0/10.0/0.0/0.0
dws008-01	0/0/3	<b>43.0</b>	69.4	1053.0	355.9	55.2/7.0/-22.2/-33.8
eil33-2	3/0/0	222.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
eilA101-2	3/0/0	331.4	<b>0.9</b>	1.0	0.0	0.0/18.2/0.0/0.0
enlight-hard	0/0/0	-	-	-	-	-/-/-/-
exp-1-500-5-5	3/0/0	<b>136.6</b>	0.1	<b>23.4</b>	0.0	-44.8/0.0/13.0/0.0
fast0507	3/0/0	25.0	<b>0.8</b>	1.0	0.0	0.0/11.1/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>650.9</b>	<b>0.7</b>	<b>43.0</b>	<b>3.2</b>	28.3/-42.9/-52.8/-100.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>13.8</b>	<b>1.9</b>	<b>12.2</b>	<b>0.0</b>	19.8/72.9/78.2/100.0
fiber	3/0/0	<b>126.5</b>	0.1	15.7	0.0	17.6/0.0/-5.1/0.0
fixnet6	3/0/0	<b>58.8</b>	0.1	31.0	1.0	-27.6/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>15.7</b>	0.1	<b>6.2</b>	<b>0.7</b>	-33.1/0.0/-53.2/-100.0
germanrr	0/3/0	4.4	<b>13.5</b>	<b>84.6</b>	<b>16.5</b>	-6.8/-13.3/-40.0/-64.2
gesa2	0/3/0	2.6	0.2	20.4	0.0	-7.7/0.0/0.0/0.0
gesa2-o	0/3/0	<b>17.4</b>	0.2	34.8	<b>1.3</b>	13.0/0.0/2.2/13.3

(continued)

Table A.25 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	<b>0.5</b>	1.0	0.0	0.0/16.7/0.0/0.0
glass4	3/0/0	<b>168.5</b>	<b>0.1</b>	<b>45.9</b>	<b>10.1</b>	75.3/66.7/56.0/68.6
gmu-35-40	3/0/0	<b>7.4</b>	0.1	<b>3.0</b>	0.0	-12.2/0.0/78.6/0.0
gmu-35-50	2/1/0	11.0	<b>0.4</b>	30.1	<b>4.5</b>	9.8/-25.0/4.1/-77.8
graph20-20-1rand	3/0/0	<b>23.3</b>	<b>2.7</b>	28.7	<b>0.3</b>	-39.9/34.1/8.3/25.0
graphdraw-domain	0/3/0	<b>52.8</b>	<b>0.1</b>	<b>15.4</b>	<b>0.3</b>	-45.5/66.7/74.6/97.1
h80x6320d	3/0/0	21.5	1.1	32.0	1.9	2.3/8.3/0.0/0.0
harp2	3/0/0	11.3	0.1	12.7	0.0	8.9/0.0/0.0/0.0
highschool1-aigio	0/3/0	inf	<b>1152.0</b>	<b>51.6</b>	<b>0.6</b>	0.0/-40.2/-70.3/-100.0
hypothyroid-k1	3/0/0	0.0	5.0	1.0	0.0	0.0/-4.0/0.0/0.0
ic97p	0/3/0	<b>11.8</b>	<b>0.7</b>	122.8	41.3	23.4/86.3/86.2/79.9
ic97t	0/0/3	12.3	4.1	1440.1	525.3	0.8/-4.9/-12.1/-40.8
icir97p	0/0/3	<b>18.6</b>	19.5	889.2	319.9	18.8/9.7/22.0/-32.6
icir97t	0/3/0	<b>13.6</b>	<b>9.7</b>	<b>376.2</b>	<b>211.5</b>	13.4/-54.6/-44.0/-39.1
irish-electricity	3/0/0	<b>7.2</b>	<b>10.0</b>	<b>6.7</b>	<b>0.0</b>	-16.7/48.5/72.3/100.0
irp	3/0/0	<b>2.5</b>	0.3	<b>3.0</b>	0.0	34.2/0.0/11.8/0.0
istanbul-no-cutoff	3/0/0	<b>24.7</b>	<b>4.1</b>	<b>12.9</b>	0.0	31.4/35.9/41.4/0.0
k1mushroom	3/0/0	18.2	41.7	1.0	0.0	0.0/-4.6/0.0/0.0
lectsched-5-obj	0/0/3	2469.7	<b>120.8</b>	1184.3	0.8	-9.1/-30.5/-23.3/88.6
leo1	3/0/0	50.7	0.1	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	45.2	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>402.8</b>	<b>0.2</b>	<b>13.9</b>	<b>0.0</b>	40.3/81.8/84.6/100.0
lotsize	3/0/0	<b>215.9</b>	0.5	47.3	<b>12.3</b>	-67.3/0.0/-5.1/-14.6
mad	3/0/0	<b>6602.2</b>	0.1	14.9	0.0	46.6/0.0/-1.3/0.0
manna81	0/3/0	13.9	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>63.5</b>	<b>13.7</b>	<b>7.7</b>	<b>0.0</b>	-29.6/72.5/78.5/100.0
map16715-04	3/0/0	<b>73.6</b>	<b>18.1</b>	<b>8.3</b>	<b>0.0</b>	17.5/68.2/82.1/100.0
markshare1	3/0/0	36348.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	53841.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	7400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	0/3/0	<b>38.8</b>	<b>0.1</b>	<b>8.3</b>	<b>0.0</b>	91.8/50.0/90.8/100.0
mas76	0/3/0	<b>12.2</b>	<b>0.1</b>	<b>5.3</b>	<b>0.0</b>	88.5/50.0/94.2/100.0
mc11	3/0/0	117.6	0.4	43.6	13.3	-8.0/0.0/-2.3/-7.5
mcsched	3/0/0	<b>21.3</b>	0.5	<b>4.6</b>	0.0	-39.4/0.0/-21.7/0.0
mik-250-20-75-4	0/3/0	<b>19.4</b>	<b>0.1</b>	<b>6.9</b>	<b>0.0</b>	68.2/50.0/82.0/100.0
milo-v12-6-r2-40-1	3/0/0	<b>125.9</b>	<b>0.8</b>	42.3	12.3	16.2/11.1/-0.7/-2.4
misc07	3/0/0	<b>22.7</b>	0.1	22.2	0.0	20.6/0.0/-9.5/0.0
mkc	0/3/0	66.5	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	3/0/0	<b>4.3</b>	<b>0.1</b>	<b>6.6</b>	0.0	69.3/66.7/66.3/0.0
modglob	3/0/0	<b>50.8</b>	0.1	<b>6.0</b>	<b>0.0</b>	52.0/0.0/80.8/100.0
momentum1	0/0/3	179.4	<b>79.8</b>	984.4	503.4	7.2/-50.5/-43.3/-29.9
msc98-ip	3/0/0	<b>12.4</b>	<b>5.4</b>	31.7	<b>1.0</b>	20.0/14.3/-3.2/-40.0
mushroom-best	0/3/0	8.40e06	<b>27.0</b>	<b>70.7</b>	<b>0.3</b>	8.4/-49.6/-43.4/82.4
mzzv11	0/3/0	21.7	<b>2.9</b>	17.7	0.0	-7.4/31.0/8.3/0.0
mzzv42z	0/3/0	<b>24.7</b>	<b>1.7</b>	<b>7.0</b>	<b>0.0</b>	20.3/65.3/70.6/100.0
n2seq36q	3/0/0	29.9	<b>0.3</b>	1.0	0.0	0.0/25.0/0.0/0.0
n3div36	3/0/0	39.2	<b>0.3</b>	1.0	0.0	0.0/25.0/0.0/0.0
n5-3	0/3/0	8.6	<b>0.4</b>	<b>27.2</b>	<b>0.3</b>	8.5/-25.0/-25.0/-100.0
neos-1122047	3/0/0	100.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>16.9</b>	<b>1.0</b>	<b>4.6</b>	<b>0.0</b>	-94.7/79.6/82.6/100.0
neos-1171737	3/0/0	<b>11.5</b>	<b>0.4</b>	<b>4.6</b>	<b>0.0</b>	-66.1/75.0/84.5/100.0
neos-1354092	0/3/0	<b>11.4</b>	<b>86.7</b>	<b>25.3</b>	0.0	37.0/50.8/32.7/0.0
neos-1445765	3/0/0	37.3	<b>0.6</b>	6.0	0.0	-5.1/25.0/-6.7/0.0
neos-1456979	0/3/0	143.2	<b>63.7</b>	887.4	125.6	4.5/-36.6/-47.9/-23.2
neos-1582420	0/3/0	75.9	<b>1.8</b>	<b>124.8</b>	<b>19.7</b>	-9.1/-16.7/-36.3/-52.3
neos-2657525-crna	0/3/0	960.7	<b>0.1</b>	<b>25.0</b>	<b>0.0</b>	5.5/50.0/40.2/100.0
neos-2746589-doon	0/0/3	<b>6.5</b>	<b>279.4</b>	720.0	26.8	81.4/-50.6/-65.5/14.4
neos-2978193-inde	3/0/0	<b>3.9</b>	0.2	<b>3.6</b>	0.0	-15.4/0.0/-36.1/0.0
neos-2987310-joes	2/1/0	<b>1.0</b>	10.5	<b>62.7</b>	15.6	-70.0/-9.5/-13.4/-5.1
neos-3004026-krka	0/0/3	0.0	<b>88.7</b>	970.8	3.3	0.0/18.6/24.5/8.3

(continued)

Table A.25 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-3024952-loue	0/0/3	838.5	<b>169.8</b>	1435.3	0.6	-3.0/-52.9/-1.5/97.8
neos-3046615-murg	0/3/0	10025.7	<b>0.1</b>	<b>106.8</b>	<b>75.2</b>	8.0/50.0/-11.7/-12.8
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/1/2	<b>135.4</b>	<b>96.8</b>	684.8	95.9	-10.7/78.9/37.5/-100.0
neos-3381206-awhea	0/0/3	4.9	<b>25.6</b>	1147.7	0.6	0.0/-28.5/-8.2/45.5
neos-3402294-bobin	3/0/0	<b>628.4</b>	<b>33.6</b>	<b>33.5</b>	<b>0.8</b>	-31.7/-40.2/-43.0/-100.0
neos-3555904-turama	2/1/0	2.0	<b>105.7</b>	<b>63.7</b>	0.4	0.0/-26.0/-50.7/0.0
neos-3627168-kasai	3/0/0	<b>1.1</b>	0.1	22.0	<b>0.3</b>	26.7/0.0/-7.3/-100.0
neos-3656078-kumeu	0/0/3	28.9	146.8	1406.8	0.3	6.2/-4.4/-26.0/66.7
neos-3754480-nidda	3/0/0	<b>2.26e05</b>	<b>0.1</b>	<b>14.5</b>	<b>0.0</b>	-99.8/50.0/78.6/100.0
neos-4300652-rahue	0/0/3	274.8	<b>523.4</b>	770.4	0.3	-3.3/-21.1/-54.0/0.0
neos-4338804-snowy	0/3/0	<b>9358.7</b>	<b>0.7</b>	<b>88.6</b>	25.8	91.8/12.5/11.8/7.9
neos-4387871-tavua	0/1/2	<b>851.2</b>	<b>20.1</b>	916.6	495.1	-11.3/12.2/-12.5/-13.7
neos-4413714-turia	3/0/0	<b>87.1</b>	<b>18.1</b>	<b>7.0</b>	<b>0.0</b>	-49.6/77.3/91.2/100.0
neos-4532248-waihi	0/1/2	949.4	<b>376.7</b>	462.9	55.6	0.0/23.0/-5.0/-35.1
neos-4647030-tutaki	3/0/0	<b>17.8</b>	<b>12.5</b>	<b>15.1</b>	0.0	19.1/28.6/14.7/0.0
neos-4722843-widden	0/3/0	<b>17.9</b>	<b>45.3</b>	<b>78.7</b>	<b>19.9</b>	90.9/17.8/14.8/22.3
neos-4738912-atrato	0/3/0	<b>7.4</b>	0.3	<b>14.3</b>	0.0	38.3/0.0/-13.3/0.0
neos-4763324-toguru	3/0/0	53.8	<b>15.7</b>	<b>11.0</b>	0.0	9.1/25.6/53.6/0.0
neos-4954672-berkel	3/0/0	<b>78.3</b>	0.1	<b>15.0</b>	<b>0.0</b>	-30.1/0.0/53.1/100.0
neos-5049753-cuanza	1/0/2	<b>52.4</b>	<b>1043.8</b>	484.3	130.3	30.7/-26.2/-32.8/-44.7
neos-5052403-cygnat	3/0/0	<b>1.0</b>	41.2	2.3	0.0	23.1/2.1/0.0/0.0
neos-5093327-huahum	3/0/0	<b>106.4</b>	<b>7.8</b>	<b>88.9</b>	<b>53.3</b>	88.3/41.8/26.3/38.5
neos-5104907-jarama	0/1/2	79.5	1738.5	730.7	93.6	-/-/-/-
neos-5107597-kakapo	3/0/0	<b>20925.9</b>	<b>2.2</b>	<b>176.8</b>	<b>141.8</b>	46.8/-18.2/-30.3/-33.1
neos-5114902-kasavu	2/0/0	35.8	2204.4	98.6	24.5	-/-/-/-
neos-5188808-nattai	3/0/0	3992.4	<b>3.7</b>	<b>19.0</b>	0.0	0.5/35.1/28.8/0.0
neos-5195221-niemur	3/0/0	<b>644.4</b>	<b>9.3</b>	19.2	0.0	16.1/-20.4/-2.6/0.0
neos-631710	3/0/0	149.4	2.3	1.0	0.0	0.0/8.0/0.0/0.0
neos-662469	0/3/0	<b>322.9</b>	<b>3.3</b>	<b>10.5</b>	<b>0.0</b>	-30.9/48.4/45.6/100.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	<b>0.4</b>	0.0	0.0	0.0/20.0/0.0/0.0
neos-848589	3/0/0	2.69e05	<b>120.8</b>	<b>89.3</b>	<b>28.7</b>	9.1/-14.5/-22.4/-27.9
neos-860300	3/0/0	<b>72.4</b>	<b>1.2</b>	<b>15.9</b>	0.0	-21.3/-66.7/-74.8/0.0
neos-873061	3/0/0	56.8	<b>22.9</b>	31.3	<b>1.3</b>	7.2/10.9/1.3/18.8
neos-911970	3/0/0	<b>207.4</b>	<b>0.1</b>	<b>19.0</b>	<b>0.0</b>	-36.4/50.0/62.0/100.0
neos-933966	3/0/0	<b>2.1</b>	<b>4.0</b>	<b>6.9</b>	0.0	99.1/-60.0/26.6/0.0
neos-950242	2/1/0	<b>165.2</b>	<b>18.2</b>	<b>59.2</b>	<b>1.9</b>	-22.3/-63.2/-63.2/-78.9
neos-957323	3/0/0	6.6	2.0	1.9	0.0	0.0/4.8/0.0/0.0
neos-960392	0/3/0	<b>1.9</b>	<b>73.6</b>	<b>357.5</b>	<b>11.1</b>	17.4/-72.6/-82.7/-81.1
neos10	0/3/0	64.5	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	<b>1.1</b>	<b>7.1</b>	838.1	45.2	21.4/23.7/28.3/-94.2
neos17	3/0/0	309.8	0.2	<b>37.2</b>	<b>3.5</b>	-6.3/0.0/-14.8/-54.3
neos20	0/0/3	<b>58.5</b>	9.1	1117.5	85.7	-21.9/7.1/5.4/-5.0
neos5	3/0/0	<b>48.4</b>	0.1	<b>2.9</b>	0.0	-14.0/0.0/23.7/0.0
neos7	0/3/0	<b>13.0</b>	<b>0.1</b>	<b>4.6</b>	0.0	-15.4/50.0/81.6/0.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>10.6</b>	<b>5.2</b>	<b>32.7</b>	<b>0.3</b>	72.3/-17.3/-21.4/-100.0
netdiversion	3/0/0	85.9	<b>186.4</b>	<b>14.0</b>	0.0	0.6/-59.8/-31.4/0.0
nexp-150-20-8-5	3/0/0	145.9	<b>0.3</b>	<b>3.0</b>	0.0	0.0/40.0/57.1/0.0
nh97p	0/0/3	9.7	12.5	861.6	308.4	4.9/8.1/21.1/-16.0
nh97t	0/0/3	<b>9.5</b>	<b>17.4</b>	1114.1	344.6	10.4/-26.4/-2.0/-5.2
noswot	0/3/0	<b>2.6</b>	0.1	<b>11.5</b>	1.4	72.9/0.0/66.5/-7.1
ns1116954	0/0/3	0.0	<b>1138.6</b>	1548.8	5.4	0.0/-58.6/-69.8/-40.7
ns1208400	0/0/3	0.0	<b>143.7</b>	930.9	6.7	0.0/-37.3/-57.5/-95.5
ns1644855	3/0/0	<b>21.6</b>	<b>221.7</b>	<b>5.0</b>	<b>0.0</b>	-97.7/43.2/85.5/100.0
ns1760995	3/0/0	<b>31.7</b>	<b>13.3</b>	<b>11.7</b>	<b>0.0</b>	-53.0/84.3/85.5/100.0
ns1830653	0/2/1	<b>526.2</b>	<b>10.8</b>	340.9	25.4	-68.8/-59.3/-82.8/-96.1
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-idx	3/0/0	37.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	3.3	<b>0.1</b>	<b>3.0</b>	0.0	0.0/66.7/84.2/0.0

(continued)

Table A.25 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
nursesched-medium-hint03	0/3/0	748.2	<b>80.5</b>	<b>46.8</b>	0.0	4.9/−82.7/−75.6/0.0
nursesched-sprint02	0/3/0	<b>47.0</b>	<b>2.7</b>	<b>15.7</b>	0.0	14.9/−29.6/−40.8/0.0
nw04	3/0/0	3.9	<b>1.3</b>	<b>4.9</b>	0.0	0.0/35.0/38.7/0.0
opm2-z10-s4	3/0/0	94.2	27.0	1.0	0.0	0.0/1.1/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	0.1	<b>5.6</b>	<b>0.0</b>	100.0/0.0/84.6/100.0
p200x1188c	3/0/0	3.9	0.2	31.0	1.0	0.0/0.0/0.0/0.0
p2756	0/3/0	75.2	0.1	5.0	0.0	8.4/0.0/0.0/0.0
peg-solitaire-a3	0/0/1	0.0	618.8	1436.0	60.0	-/-/-/-
pg	3/0/0	<b>4.1</b>	<b>0.1</b>	<b>10.9</b>	<b>0.0</b>	73.5/66.7/78.9/100.0
pg5-34	3/0/0	7.6	<b>0.1</b>	<b>7.4</b>	<b>0.0</b>	−6.6/75.0/85.8/100.0
physiciansched3-3	0/0/3	<b>906.9</b>	<b>142.5</b>	771.9	76.6	−99.0/−61.8/−94.0/−98.7
physiciansched6-2	0/0/3	<b>2.7</b>	<b>68.0</b>	976.2	65.2	44.9/19.4/−24.2/−46.6
piperout-08	0/0/3	<b>57.7</b>	<b>38.7</b>	973.1	27.5	85.4/44.1/43.1/17.4
piperout-27	0/0/3	<b>47.2</b>	<b>40.7</b>	794.7	10.0	79.3/38.3/33.6/43.2
pk1	3/0/0	<b>222.2</b>	<b>0.1</b>	<b>32.3</b>	<b>0.3</b>	81.4/50.0/44.3/96.6
pp08a	3/0/0	53.4	0.1	16.7	0.0	8.6/0.0/−6.6/0.0
pp08aCUTS	3/0/0	<b>25.0</b>	0.1	<b>10.5</b>	0.0	28.8/0.0/12.5/0.0
proteindesign121hz512p9	0/2/1	<b>18.8</b>	<b>78.9</b>	353.8	36.5	−87.2/−93.7/−93.1/−99.2
proteindesign122trx11p8	0/3/0	<b>12.2</b>	<b>16.5</b>	<b>81.3</b>	<b>7.1</b>	−91.0/−93.9/−95.1/−100.0
protfold	1/2/0	59.9	<b>10.6</b>	<b>89.7</b>	<b>3.6</b>	9.2/−20.8/−57.9/−100.0
qap10	3/0/0	<b>17.1</b>	<b>17.0</b>	<b>4.0</b>	0.0	11.9/−19.4/−50.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	<b>289.8</b>	0.5	24.0	<b>0.3</b>	−17.1/0.0/5.1/−100.0
rB10-011001	3/0/0	<b>230.7</b>	0.5	24.0	<b>0.3</b>	−11.5/0.0/8.7/−100.0
rB11-010000	3/0/0	279.8	<b>1.6</b>	<b>36.3</b>	<b>1.0</b>	3.1/−18.8/−17.4/−40.0
rB11-110001	3/0/0	<b>170.2</b>	<b>3.1</b>	<b>30.7</b>	<b>0.6</b>	18.0/−16.1/−24.1/−50.0
rB12-111111	1/1/1	<b>71.4</b>	<b>18.6</b>	292.9	35.1	20.6/59.9/49.0/−90.9
rC10-001000	3/0/0	<b>182.3</b>	<b>0.3</b>	<b>33.0</b>	0.0	33.7/−33.3/−15.5/0.0
rC10-100001	3/0/0	397.5	<b>3.8</b>	91.8	<b>1.6</b>	2.7/22.4/9.6/−50.0
rC11-010100	3/0/0	347.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>258.2</b>	<b>7.7</b>	<b>69.6</b>	<b>2.0</b>	19.8/−33.8/−47.7/−60.0
rC12-111100	3/0/0	194.9	0.3	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>177.7</b>	<b>2.8</b>	<b>107.2</b>	<b>10.5</b>	−14.4/−35.7/−36.3/−65.7
radiationm40-10-02	0/3/0	<b>3603.3</b>	<b>24.2</b>	<b>239.5</b>	<b>24.6</b>	−88.0/−33.1/−40.0/−63.4
rail01	2/0/0	28.1	1647.3	19.8	0.0	-/-/-/-
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	23.3	<b>1.0</b>	1.0	0.0	0.0/16.7/0.0/0.0
ran14x18-disj-8	3/0/0	<b>37.5</b>	<b>0.2</b>	23.5	<b>0.8</b>	−55.7/33.3/−3.0/−62.5
rd-rplusc-21	0/0/3	56.7	<b>42.3</b>	1112.5	427.7	2.4/−14.4/−22.1/−15.7
reblock115	3/0/0	<b>9.1</b>	<b>1.3</b>	54.6	<b>4.0</b>	18.8/18.8/1.4/35.5
rmatr100-p10	3/0/0	<b>3.2</b>	<b>0.7</b>	<b>5.3</b>	0.0	89.2/−14.3/−56.6/0.0
rmatr200-p5	3/0/0	17.7	<b>27.6</b>	<b>6.6</b>	0.0	9.2/−48.9/−69.7/0.0
rocl-4-11	0/0/3	<b>82.0</b>	23.5	1189.2	311.0	−15.6/−9.8/−21.6/−66.6
rocll-5-11	0/0/3	86.1	<b>49.6</b>	984.5	364.6	4.8/−83.1/−84.1/−85.6
roi2alpha3n4	3/0/0	<b>49.7</b>	<b>6.6</b>	<b>7.0</b>	<b>0.0</b>	20.4/80.2/79.6/100.0
roi5alpha10n8	3/0/0	56.6	<b>92.3</b>	<b>8.0</b>	0.0	5.8/79.3/72.4/0.0
roll3000	0/3/0	<b>35.4</b>	1.0	53.6	4.6	−26.0/9.1/−9.7/−2.2
rout	0/3/0	46.4	<b>0.1</b>	35.0	1.6	6.3/50.0/0.6/5.9
s100	3/0/0	<b>7.4</b>	280.6	<b>7.8</b>	0.0	−77.0/7.3/−15.4/0.0
s250r10	3/0/0	0.1	50.7	2.0	0.0	0.0/5.1/0.0/0.0
satellites2-40	0/2/1	255.5	<b>330.1</b>	253.2	105.4	−4.0/−86.6/−86.2/−97.4
satellites2-60-fs	1/1/1	<b>236.3</b>	<b>239.7</b>	149.4	32.6	−62.1/−90.6/−76.6/−91.7
savsched1	0/3/0	<b>12.7</b>	<b>144.9</b>	<b>8.3</b>	0.0	−37.8/23.8/32.5/0.0
sct2	3/0/0	<b>37.6</b>	<b>0.2</b>	<b>8.3</b>	<b>0.0</b>	−22.3/66.7/68.2/100.0
set1ch	3/0/0	<b>74.9</b>	0.1	31.0	1.0	12.5/0.0/0.0/0.0
seymour	3/0/0	12.7	<b>0.6</b>	1.0	0.0	0.0/14.3/0.0/0.0
seymour1	3/0/0	<b>11.3</b>	<b>1.5</b>	<b>3.3</b>	0.0	−87.6/44.4/56.6/0.0
sing326	3/0/0	<b>63.6</b>	<b>13.2</b>	<b>11.1</b>	<b>0.0</b>	−83.3/46.6/67.4/100.0
sing44	3/0/0	<b>17.9</b>	<b>9.6</b>	<b>4.6</b>	<b>0.0</b>	−58.7/63.6/88.1/100.0
snp-02-004-104	0/3/0	<b>288.0</b>	<b>22.8</b>	34.0	<b>1.6</b>	−99.4/−13.6/−1.2/15.8

(continued)

Table A.25 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
sorrell3	3/0/0	76.3	<b>0.8</b>	1.0	0.0	0.0/11.1/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.7	<b>1.6</b>	0.0/0.0/-1.3/-18.8
sp97ar	3/0/0	25.7	<b>0.8</b>	2.2	0.0	3.4/11.1/0.0/0.0
sp98ar	3/0/0	24.1	<b>0.5</b>	1.0	0.0	0.0/16.7/0.0/0.0
splince1k1	3/0/0	99.0	57.5	<b>9.0</b>	0.0	-0.4/7.4/30.8/0.0
square41	0/0/0	-	-	-	-	-/-/-/-
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>41.2</b>	<b>90.6</b>	<b>7.5</b>	0.0	75.8/17.7/44.9/0.0
supportcase12	0/3/0	<b>5.8</b>	<b>4.7</b>	<b>4.3</b>	0.0	-69.0/67.8/79.5/0.0
supportcase18	3/0/0	37.5	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>268.3</b>	0.2	<b>72.0</b>	<b>41.6</b>	97.1/0.0/19.7/34.3
supportcase33	0/2/1	<b>76.3</b>	<b>25.4</b>	316.7	53.1	-15.5/-45.7/-61.7/-72.7
supportcase40	3/0/0	<b>48.7</b>	<b>1.5</b>	<b>8.0</b>	0.0	-63.9/64.3/51.8/0.0
supportcase42	0/3/0	<b>16.8</b>	4.5	<b>9.8</b>	0.0	31.1/-6.7/15.5/0.0
supportcase6	3/0/0	0.4	<b>5.8</b>	<b>6.1</b>	0.0	0.0/56.4/49.2/0.0
supportcase7	3/0/0	15.1	<b>4.6</b>	<b>11.9</b>	0.0	-5.3/44.6/54.2/0.0
swath	0/1/2	197.6	<b>68.7</b>	746.3	309.0	-8.1/-80.3/-74.8/-80.7
swath1	3/0/0	<b>12.0</b>	<b>1.7</b>	61.6	<b>14.1</b>	80.1/26.1/1.0/10.2
swath3	3/0/0	<b>15.4</b>	<b>1.3</b>	43.1	<b>5.6</b>	53.6/13.3/-0.5/-42.9
t1717	1/2/0	<b>96.8</b>	138.4	<b>68.3</b>	<b>0.3</b>	46.0/-8.7/-36.3/-100.0
tbfp-network	3/0/0	<b>19.3</b>	<b>9.1</b>	<b>9.7</b>	0.0	90.3/59.4/30.7/0.0
thor50dday	3/0/0	<b>325.5</b>	7.9	26.2	<b>2.1</b>	-20.8/-8.9/-6.5/-19.0
timtab1	0/3/0	52.4	<b>1.1</b>	<b>151.3</b>	<b>62.8</b>	5.6/-45.5/-24.9/-55.6
timtab2	0/0/3	75.1	<b>11.1</b>	1188.0	421.9	-2.0/-47.7/-33.4/-35.9
tr12-30	3/0/0	<b>36.4</b>	0.2	<b>37.8</b>	<b>5.8</b>	50.1/0.0/-16.1/-72.4
traininstance2	0/1/2	<b>335.7</b>	<b>4.5</b>	862.7	226.2	-27.4/-26.7/-24.7/-69.7
traininstance6	0/3/0	<b>1018.5</b>	<b>0.5</b>	195.1	41.8	-54.7/58.3/36.2/0.7
trento1	3/0/0	<b>91.6</b>	<b>14.6</b>	<b>15.9</b>	0.0	51.0/-45.2/-41.5/0.0
triptim1	0/3/0	0.1	<b>19.5</b>	3.6	0.0	0.0/16.3/10.0/0.0
uccase12	3/0/0	1.9	9.6	16.6	0.0	0.0/6.8/-6.0/0.0
uccase9	3/0/0	<b>374.7</b>	<b>10.4</b>	27.5	2.8	93.3/82.0/85.5/96.2
uct-subprob	3/0/0	<b>16.7</b>	<b>0.4</b>	7.3	0.0	-25.7/33.3/5.2/0.0
unitcal-7	0/1/2	<b>39.8</b>	<b>95.1</b>	740.8	95.5	-32.7/30.9/25.3/34.5
var-smallemercy-m6j6	3/0/0	<b>23.7</b>	<b>2.8</b>	<b>6.3</b>	<b>0.0</b>	90.8/88.3/90.7/100.0
vpm2	3/0/0	49.6	0.1	<b>27.2</b>	<b>0.3</b>	-9.3/0.0/-25.0/-100.0
wachplan	0/3/0	0.0	<b>2.2</b>	25.8	<b>0.3</b>	0.0/26.7/2.6/-100.0
Geom. means		(269 instances)		(220 instances)		
FP		46.1	5.1	15.0	1.1	
FP+(3,sv,h,c,Δ)		<b>43.9</b>	<b>5.0</b>	<b>11.9</b>	<b>0.8</b>	

Table A.26.: Performance of FP with CPLEX

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
10teams	2/1/0	7.0	1.7	47.6	0.0
30n20b8	0/0/3	222.2	19.9	1149.6	266.9
50v-10	0/3/0	114.5	0.2	29.2	0.6
CMS750-4	3/0/0	59.9	3.4	65.2	13.7
a1c1s1	3/0/0	35.7	0.2	31.7	1.6
academictimetables-small	0/0/3	inf	2179.8	1043.8	0.0
aflow30a	3/0/0	265.0	0.1	38.9	4.9
aflow40b	3/0/0	251.1	0.2	44.3	6.5
air04	3/0/0	0.9	21.6	9.6	0.0
air05	3/0/0	1.5	3.7	4.3	0.0
app1-1	3/0/0	0.0	0.2	35.7	4.3
app1-2	3/0/0	43.1	8.7	40.5	8.0
arki001	0/1/2	2.1	6.5	373.8	80.8
assign1-5-8	3/0/0	1.6	0.1	20.2	0.0

(continued)

Table A.26 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
atlanta-ip	0/3/0	32.5	45.9	47.0	0.7
b1c1s1	3/0/0	171.8	0.2	33.7	3.6
bab2	0/0/2	46.8 <sup>(2)</sup>	2773.6	966.8	228.2
bab6	1/0/2	29.9	347.4	409.5	69.4
beasleyC3	3/0/0	12.3	0.1	35.0	4.8
binkar10-1	3/0/0	3.9	0.1	6.0	0.0
blp-ar98	3/0/0	56.1	1.2	10.7	0.0
blp-ic98	3/0/0	21.6	0.9	6.6	0.0
bnatt400	0/0/0	-	-	-	-
bppc4-08	3/0/0	51.3	0.4	61.6	9.0
brazil3	0/3/0	572.2	27.8	24.9	0.0
buildingenergy	0/1/0	0.6 <sup>(1)</sup>	3055.2	11.0	0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0
cbs-cta	3/0/0	inf	1.7	31.3	1.3
chromaticindex1024-7	3/0/0	0.0	7.0	2.0	0.0
chromaticindex512-7	3/0/0	0.0	3.0	2.0	0.0
cmflsp50-24-8-8	0/0/3	21.3	242.2	1236.3	349.3
co-100	3/0/0	347.0	3.9	19.9	0.0
cod105	3/0/0	100.0	2.0	1.0	0.0
comp07-2idx	0/3/0	4002.2	18.2	25.9	0.0
comp21-2idx	0/3/0	347.5	17.2	21.2	0.0
cost266-UUE	3/0/0	35.5	0.4	27.1	0.3
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-
csched007	0/2/1	92.9	4.2	774.1	167.5
csched008	0/3/0	8.4	1.1	223.7	53.9
cvs16r128-89	3/0/0	97.9	0.1	1.0	0.0
dano3-3	3/0/0	0.0	47.1	14.5	0.0
dano3-5	3/0/0	0.2	139.0	29.6	0.8
dano3mip	3/0/0	16.1	1284.6	70.0	17.9
danooint	3/0/0	27.8	1.0	86.6	27.6
disctom	3/0/0	0.0	2.8	3.0	0.0
drayage-100-23	3/0/0	31.0	0.3	18.9	0.0
drayage-25-23	3/0/0	29.6	0.2	7.0	0.0
ds	2/0/0	1030.3 <sup>(2)</sup>	3158.8	66.0	0.0
dws008-01	0/0/1	61.9 <sup>(1)</sup>	40.2	729.0	175.0
eil33-2	3/0/0	52.9	1.4	29.4	0.4
eilA101-2	0/1/2	393.3	3320.2	699.7	6.6
enlight-hard	0/0/3	0.0	0.8	803.8	409.6
exp-1-500-5-5	3/0/0	76.3	0.1	26.9	0.0
fast0507	3/0/0	23.8	1.4	1.0	0.0
fastxgemm-n2r6s0t2	3/0/0	522.2	0.1	16.6	0.0
fhnw-binpack4-48	0/0/0	-	-	-	-
fiball	0/3/0	12.8	3.8	53.3	4.9
fiber	3/0/0	173.2	0.1	1.0	0.0
fixnet6	3/0/0	27.7	0.1	31.0	1.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0
gen-ip054	0/3/0	15.0	0.1	1.3	0.0
germanrr	0/3/0	2.5	4.6	26.7	0.0
gesa2	0/3/0	2.1	0.1	20.4	0.0
gesa2-o	0/3/0	21.0	0.1	34.0	2.2
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-
glass-sc	3/0/0	13.4	0.2	1.0	0.0
glass4	3/0/0	490.8	0.1	141.2	70.1
gmu-35-40	3/0/0	4.6	0.2	69.2	8.2
gmu-35-50	3/0/0	1.1	0.1	13.3	0.0
graph20-20-1rand	3/0/0	28.0	7.4	23.0	0.0
graphdraw-domain	0/3/0	45.5	0.1	71.2	14.5
h80x6320d	3/0/0	30.3	1.3	33.3	2.2
harp2	3/0/0	11.3	0.1	13.0	0.0
highschool1-aigio	0/3/0	inf	295.0	29.5	0.6
hypothyroid-k1	3/0/0	0.0	30.9	1.0	0.0

(continued)

Table A.26 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
ic97p	0/0/3	15.5	3.3	1045.8	223.5
ic97t	0/3/0	12.4	0.9	696.3	247.5
icir97p	0/0/3	21.1	13.5	969.8	133.0
icir97t	0/3/0	14.3	1.7	160.2	99.5
irish-electricity	0/0/3	45.2	1339.5	1241.2	26.8
irp	3/0/0	1.0	0.9	13.9	0.0
istanbul-no-cutoff	3/0/0	23.0	3.3	9.0	0.0
k1mushroom	3/0/0	18.2	26.0	1.0	0.0
lectsched-5-obj	0/0/3	2670.0	85.9	1016.9	0.3
leo1	3/0/0	50.6	0.2	1.0	0.0
leo2	3/0/0	48.3	0.2	1.0	0.0
liu	3/0/0	674.7	0.5	93.3	39.6
lotsize	3/0/0	62.8	0.3	46.6	9.1
mad	3/0/0	9392.7	0.1	14.0	0.0
manna81	0/3/0	1.1	0.1	2.6	0.0
map10	3/0/0	30.0	63.5	40.1	4.6
map16715-04	3/0/0	89.2	107.2	46.3	8.9
markshare1	3/0/0	48650.9	0.1	70.3	16.3
markshare2	3/0/0	89202.7	0.1	70.3	15.6
markshare-4-0	3/0/0	18064.6	0.1	65.0	15.9
mas74	0/3/0	53.6	0.1	90.0	14.6
mas76	0/3/0	19.3	0.1	90.7	21.5
mc11	3/0/0	106.3	0.4	42.3	12.3
mcsched	3/0/0	12.3	0.2	3.6	0.0
mik-250-20-75-4	0/3/0	61.1	0.1	38.3	4.5
milo-v12-6-r2-40-1	3/0/0	149.8	1.4	42.0	11.9
misc07	3/0/0	32.1	0.1	22.8	0.3
mkc	0/3/0	70.8	0.1	2.0	0.0
mod011	0/0/0	-	-	-	-
modglob	3/0/0	0.2	0.1	31.3	1.3
momentum1	0/2/1	273.2	139.8	954.3	725.5
msc98-ip	0/3/0	13.4	2.5	15.1	0.0
mushroom-best	0/3/0	9.67e06	18.5	47.0	1.0
mzzv11	0/3/0	15.4	2.9	21.2	0.0
mzzv42z	0/3/0	22.9	3.1	24.2	0.3
n2seq36q	3/0/0	8.3	0.4	2.0	0.0
n3div36	3/0/0	43.5	0.3	1.0	0.0
n5-3	0/3/0	33.0	0.2	20.4	0.0
neos-1122047	3/0/0	0.6	0.3	1.0	0.0
neos-1171448	3/0/0	7.4	2.9	13.2	0.0
neos-1171737	3/0/0	3.8	1.7	24.6	0.0
neos-1354092	0/3/0	16.3	101.5	33.9	0.0
neos-1445765	3/0/0	24.7	1.7	11.3	0.0
neos-1456979	0/2/1	166.2	34.5	558.8	85.9
neos-1582420	0/3/0	74.4	1.1	112.0	19.0
neos-2657525-crna	0/2/1	1010.1	0.6	109.8	7.1
neos-2746589-doon	0/0/2	43.6 <sup>(2)</sup>	180.2	694.0	268.0
neos-2978193-inde	3/0/0	28.1	0.1	2.6	0.0
neos-2987310-joes	3/0/0	0.6	11.6	51.3	11.5
neos-3004026-krka	0/0/2	0.0 <sup>(2)</sup>	85.7	1322.7	2.2
neos-3024952-loue	0/1/2	791.8	42.0	1255.1	25.6
neos-3046615-murg	0/3/0	13613.0	0.1	104.1	77.9
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0
neos-3216931-puriri	0/0/0	-	-	-	-
neos-3381206-awhea	0/0/3	4.9	8.8	852.9	0.0
neos-3402294-bobin	3/0/0	701.5	9.6	15.1	0.0
neos-3555904-turama	0/1/2	8.4	1878.4	593.4	92.5
neos-3627168-kasai	3/0/0	2.2	0.1	27.2	0.3
neos-3656078-kumeu	0/0/0	-	-	-	-
neos-3754480-nidda	3/0/0	15.3	0.1	68.0	14.3
neos-4300652-rahue	0/0/3	206.4	865.1	762.0	0.3

(continued)

Table A.26 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
neos-4338804-snowy	0/3/0	1.29e05	0.7	194.6	46.0
neos-4387871-tavua	0/1/2	818.5	9.3	588.1	289.1
neos-4413714-turia	3/0/0	25054.5	514.6	89.3	12.6
neos-4532248-waihi	0/0/3	949.4	824.6	871.4	40.5
neos-4647030-tutaki	3/0/0	31.4	27.0	20.4	0.0
neos-4722843-widden	0/3/0	38.9	16.7	48.6	9.3
neos-4738912-atrato	0/3/0	12.1	0.3	17.8	0.0
neos-4763324-toguru	3/0/0	30.7	46.0	21.3	0.0
neos-4954672-berkel	3/0/0	45.8	0.1	32.3	2.0
neos-5049753-cuanza	0/2/1	68.3	836.6	699.4	130.8
neos-5052403-cygnat	3/0/0	0.3	71.6	2.0	0.0
neos-5093327-huahum	3/0/0	206.3	15.9	99.9	32.2
neos-5104907-jarama	0/0/0	-	-	-	-
neos-5107597-kakapo	1/2/0	35678.9	19.4	409.4	369.7
neos-5114902-kasavu	0/0/0	-	-	-	-
neos-5188808-nattai	3/0/0	4342.7	5.0	25.6	0.0
neos-5195221-niemur	3/0/0	953.4	7.1	11.4	0.0
neos-631710	3/0/0	173.9	1.6	1.0	0.0
neos-662469	0/3/0	1527.8	4.1	2.9	0.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0
neos-827175	3/0/0	0.0	1.1	3.0	0.0
neos-848589	3/0/0	50673.0	65.7	65.5	18.3
neos-860300	3/0/0	36.1	0.2	4.0	0.0
neos-873061	3/0/0	55.4	51.6	31.3	1.3
neos-911970	3/0/0	172.5	0.1	52.0	4.9
neos-933966	3/0/0	123.3	2.2	9.8	0.0
neos-950242	3/0/0	79.8	20.8	22.6	0.4
neos-957323	3/0/0	11.4	1.9	1.3	0.0
neos-960392	3/0/0	0.8	4.0	7.0	0.0
neos10	0/3/0	127.1	0.1	2.9	0.0
neos16	0/0/1	1.3 <sup>(1)</sup>	12.0	2042.0	5.0
neos17	3/0/0	253.5	0.1	31.7	1.6
neos20	0/0/1	55.3 <sup>(1)</sup>	5.5	1114.0	93.0
neos5	3/0/0	26.1	0.1	3.3	0.0
neos7	0/3/0	21.0	0.1	45.3	6.3
neos8	0/3/0	20.7	0.1	2.6	0.0
net12	3/0/0	30.5	6.0	35.5	0.3
netdiversion	3/0/0	90.5	49.9	9.7	0.0
nexp-150-20-8-5	3/0/0	142.4	0.1	1.0	0.0
nh97p	0/0/3	12.5	8.1	1003.5	214.1
nh97t	0/1/2	11.2	8.5	905.6	222.0
noswot	0/3/0	6.7	0.1	33.8	1.0
ns1116954	2/1/0	0.0	232.9	130.4	5.2
ns1208400	2/1/0	0.0	96.9	189.3	0.0
ns1644855	3/0/0	1.1	1443.4	45.2	5.7
ns1760995	3/0/0	18.7	306.5	79.9	3.0
ns1830653	0/2/1	242.3	6.7	408.7	74.4
ns1952667	0/0/0	-	-	-	-
nsrand-ipx	3/0/0	47.0	0.1	1.0	0.0
nu25-pr12	0/3/0	2.6	0.3	15.7	0.0
nursesched-medium-hint03	0/3/0	736.8	14.0	13.8	0.0
nursesched-sprint02	0/3/0	94.0	2.4	11.6	0.0
nw04	3/0/0	22.2	2.1	13.0	0.0
opm2-z10-s4	3/0/0	94.2	68.9	1.0	0.0
opt1217	3/0/0	1.4	0.1	36.1	1.7
p200x1188c	3/0/0	3.9	0.1	31.0	1.0
p2756	0/3/0	67.7	0.1	5.0	0.0
peg-solitaire-a3	0/1/2	0.0	2081.6	1007.8	47.4
pg	3/0/0	15.5	0.1	51.7	19.2
pg5-34	3/0/0	7.1	0.2	52.0	13.6
physiciansched3-3	3/0/0	12.3	622.5	35.3	0.7

(continued)



Table A.26 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
physiciansched6-2	2/1/0	67.9	37.9	266.2	1.7
piperout-08	0/0/3	31.9	28.5	870.6	9.9
piperout-27	0/0/3	37.1	40.5	962.7	5.5
pk1	3/0/0	1535.3	0.1	58.7	8.9
pp08a	3/0/0	53.9	0.1	15.6	0.0
pp08aCUTS	3/0/0	26.4	0.1	12.0	0.0
proteindesign121hz512p9	0/1/2	3.2	143.7	503.6	10.6
proteindesign122trx11p8	0/0/2	1.1 <sup>(2)</sup>	3036.5	924.3	17.0
protfold	3/0/0	66.5	6.5	26.5	0.4
qap10	3/0/0	0.0	11.9	2.0	0.0
qiu	3/0/0	1530.9	0.1	3.3	0.0
rB10-011000	3/0/0	240.2	0.4	25.3	0.0
rB10-011001	3/0/0	204.1	0.4	26.3	0.0
rB11-010000	3/0/0	289.5	1.2	29.6	0.3
rB11-110001	3/0/0	178.8	3.4	29.3	0.0
rB12-111111	1/1/1	71.4	30.4	481.8	8.6
rC10-001000	3/0/0	288.4	0.1	28.3	0.3
rC10-100001	3/0/0	436.5	2.4	107.3	1.7
rC11-010100	3/0/0	347.0	0.3	1.0	0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0
rC12-100000	3/0/0	293.9	3.8	29.7	0.8
rC12-111100	3/0/0	194.9	0.4	1.0	0.0
radiationm18-12-05	0/3/0	2942.8	4.6	247.1	27.3
radiationm40-10-02	0/0/3	1550.2	88.4	1174.2	16.7
rail01	3/0/0	36.6	1779.1	32.1	0.3
rail02	3/0/0	6.1	1788.1	4.0	0.0
rail507	3/0/0	23.8	2.1	1.0	0.0
ran14x18-disj-8	3/0/0	16.6	0.1	22.8	0.3
rd-rplusc-21	0/0/3	101.5	128.8	795.7	394.1
reblock115	0/3/0	11.6	3.8	41.6	1.9
rmatr100-p10	3/0/0	29.5	0.6	2.3	0.0
rmatr200-p5	3/0/0	19.5	17.9	2.0	0.0
rocl-4-11	0/0/3	69.1	21.1	791.1	30.6
rocl-5-11	0/0/3	87.5	70.3	793.8	88.5
roi2alpha3n4	3/0/0	51.9	28.3	33.6	1.6
roi5alpha10n8	3/0/0	66.7	459.9	29.7	0.0
roll3000	0/3/0	33.5	0.7	50.0	4.3
rout	0/3/0	35.4	0.1	34.0	1.3
s100	3/0/0	3.0	281.3	6.6	0.0
s250r10	3/0/0	0.1	63.6	2.0	0.0
satellites2-40	3/0/0	330.1	766.9	38.3	4.5
satellites2-60-fs	3/0/0	398.0	350.3	40.4	5.5
savsched1	3/0/0	6.2	113.5	11.3	0.0
sct2	3/0/0	13.2	0.2	22.3	0.0
set1ch	3/0/0	56.0	0.1	31.0	1.0
seymour	3/0/0	12.3	0.9	1.0	0.0
seymour1	3/0/0	1.0	5.3	8.0	0.0
sing326	3/0/0	39.1	21.5	39.3	3.6
sing44	3/0/0	11.5	17.6	36.7	3.3
snp-02-004-104	0/3/0	2.5	43.2	33.3	1.6
sorrell3	3/0/0	73.7	0.7	1.0	0.0
sp150x300d	3/0/0	2.9	0.1	31.3	1.3
sp97ar	3/0/0	22.9	47.5	2.2	0.0
sp98ar	3/0/0	29.0	41.0	1.0	0.0
splice1k1	3/0/0	98.6	122.3	13.0	0.0
square41	0/3/0	6.7	799.4	10.0	0.0
square47	0/3/0	12.3	1556.7	11.0	0.0
supportcase10	3/0/0	194.8	1168.9	13.0	0.0
supportcase12	0/3/0	5.0	30.5	24.8	0.4
supportcase18	3/0/0	77.1	0.1	1.0	0.0
supportcase26	3/0/0	45.7	0.1	89.7	63.7

(continued)

Table A.26 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
supportcase33	0/3/0	80.9	29.9	230.5	81.2
supportcase40	3/0/0	17.6	6.1	16.6	0.0
supportcase42	0/3/0	15.7	8.6	10.7	0.0
supportcase6	3/0/0	2.7	95.6	14.5	0.0
supportcase7	3/0/0	46.4	65.8	24.4	0.0
swath	1/2/0	202.2	20.0	184.8	56.1
swath1	2/1/0	69.5	3.9	62.0	16.3
swath3	3/0/0	11.3	3.7	59.4	15.4
t1717	3/0/0	203.7	262.7	58.0	0.3
tbfp-network	3/0/0	58.0	71.6	7.0	0.0
thor50dday	3/0/0	257.8	5.3	24.5	1.7
timtab1	0/3/0	75.3	0.1	105.1	33.1
timtab2	0/2/1	85.9	2.5	594.5	222.3
tr12-30	3/0/0	73.7	0.1	31.0	1.0
traininstance2	0/0/3	345.5	24.9	1231.8	71.8
traininstance6	0/2/1	608.3	8.4	632.4	48.7
trento1	3/0/0	12.6	31.1	3.3	0.0
triptim1	0/3/0	0.1	129.9	5.5	0.0
uccase12	3/0/0	0.0	17.4	20.5	0.0
uccase9	1/1/1	978.6	44.9	218.2	84.0
uct-subprob	3/0/0	13.9	0.1	7.3	0.0
unitcal-7	0/0/3	46.4	153.5	977.2	180.0
var-smallemary-m6j6	3/0/0	58.0	24.3	67.0	9.3
vpm2	3/0/0	35.0	0.1	31.0	1.0
wachplan	0/3/0	0.0	1.3	24.3	0.0

Table A.27.: Performance of FP+( $c, \Delta$ ) with CPLEX

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	2/1/0	6.6	<b>1.3</b>	<b>32.0</b>	<b>0.3</b>	5.7/23.5/32.8/-100.0
30n20b8	0/0/3	<b>265.0</b>	<b>17.4</b>	1042.6	224.6	-16.2/12.6/9.3/15.8
50v-10	0/3/0	<b>134.9</b>	0.2	<b>21.7</b>	<b>0.3</b>	-15.1/0.0/25.7/50.0
CMS750-4	3/0/0	<b>87.0</b>	3.3	65.2	<b>16.0</b>	-31.1/2.9/0.0/-14.4
a1c1s1	3/0/0	<b>41.8</b>	0.2	31.3	<b>1.3</b>	-14.6/0.0/1.3/18.8
academictimetablesmall	0/0/3	inf	2193.6	877.3	0.0	0.0/-0.6/16.0/0.0
aflow30a	3/0/0	<b>169.6</b>	0.1	<b>33.2</b>	<b>2.1</b>	36.0/0.0/14.7/57.1
aflow40b	3/0/0	<b>323.2</b>	0.2	<b>36.5</b>	<b>4.2</b>	-22.3/0.0/17.6/35.4
air04	3/0/0	<b>2.7</b>	<b>17.8</b>	<b>5.5</b>	0.0	-66.7/17.6/42.7/0.0
air05	3/0/0	<b>2.5</b>	<b>4.5</b>	<b>7.4</b>	0.0	-40.0/-17.8/-41.9/0.0
app1-1	3/0/0	0.0	0.2	34.6	<b>3.8</b>	0.0/0.0/3.1/11.6
app1-2	3/0/0	45.5	<b>10.4</b>	<b>53.5</b>	<b>14.5</b>	-5.3/-16.3/-24.3/-44.8
arki001	0/1/2	<b>2.4</b>	<b>12.0</b>	777.6	180.9	-12.5/-45.8/-51.9/-55.3
assign1-5-8	3/0/0	<b>8.4</b>	0.1	<b>5.0</b>	0.0	-81.0/0.0/75.2/0.0
atlanta-ip	0/3/0	<b>14.7</b>	<b>37.2</b>	<b>12.1</b>	<b>0.0</b>	54.8/19.0/74.3/100.0
b1c1s1	3/0/0	<b>116.0</b>	0.2	34.0	4.0	32.5/0.0/-0.9/-10.0
bab2	1/0/2	56.1	1674.4	519.6	92.0	-/-/-/-
bab6	3/0/0	<b>53.6</b>	<b>193.0</b>	121.0	16.6	-44.2/44.4/70.5/76.1
beasleyC3	3/0/0	11.8	0.1	35.0	4.8	4.1/0.0/0.0/0.0
binkar10-1	3/0/0	<b>2.3</b>	0.1	<b>10.3</b>	0.0	41.0/0.0/-41.7/0.0
blp-ar98	3/0/0	61.6	1.2	<b>9.3</b>	0.0	-8.9/0.0/13.1/0.0
blp-ic98	3/0/0	19.9	<b>0.7</b>	<b>4.0</b>	0.0	7.9/22.2/39.4/0.0
bnatt400	0/0/0	-	-	-	-	-/-/-/-
bppc4-08	3/0/0	<b>31.8</b>	<b>0.1</b>	<b>5.6</b>	<b>0.0</b>	38.0/75.0/90.9/100.0
brazil3	0/3/0	<b>1100.5</b>	<b>55.3</b>	<b>46.7</b>	<b>0.3</b>	-48.0/-49.7/-46.7/-100.0
buildingenergy	0/3/0	1.0	1186.8	3.0	0.0	-/-/-/-
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	<b>0.0</b>	<b>1.9</b>	32.3	<b>1.9</b>	100.0/-10.5/-3.1/-31.6
chromaticindex1024-7	3/0/0	0.0	<b>32.2</b>	<b>4.6</b>	0.0	0.0/-78.3/-56.5/0.0

(continued)

Table A.27 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
chromaticindex512-7	3/0/0	0.0	<b>9.5</b>	<b>4.2</b>	0.0	0.0/-68.4/-52.4/0.0
cmflsp50-24-8-8	0/0/3	20.9	235.4	1211.0	353.1	1.9/2.8/2.0/-1.1
co-100	3/0/0	377.2	<b>3.3</b>	<b>16.8</b>	0.0	-8.0/15.4/15.6/0.0
cod105	3/0/0	100.0	2.0	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	<b>3070.0</b>	<b>20.8</b>	<b>50.9</b>	<b>1.3</b>	23.3/-12.5/-49.1/-100.0
comp21-2idx	0/3/0	<b>508.0</b>	<b>30.4</b>	<b>59.6</b>	<b>0.6</b>	-31.6/-43.4/-64.4/-100.0
cost266-UUE	3/0/0	<b>44.9</b>	<b>0.5</b>	<b>22.0</b>	0.3	-20.9/-20.0/18.8/0.0
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/0/3	<b>72.6</b>	<b>5.9</b>	924.1	206.8	21.9/-28.8/-16.2/-19.0
csched008	1/2/0	9.1	<b>0.7</b>	<b>152.4</b>	<b>39.5</b>	-7.7/36.4/31.9/26.7
cvs16r128-89	3/0/0	97.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	<b>70.3</b>	<b>2.0</b>	0.0	0.0/-33.0/86.2/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>69.4</b>	<b>2.0</b>	<b>0.0</b>	-33.3/50.1/93.2/100.0
dano3mip	3/0/0	15.4	<b>105.2</b>	<b>5.0</b>	<b>0.0</b>	4.3/91.8/92.9/100.0
danooint	3/0/0	<b>25.0</b>	<b>0.4</b>	<b>50.4</b>	<b>5.6</b>	10.1/60.0/41.8/79.7
disctom	3/0/0	0.0	<b>2.4</b>	3.0	0.0	0.0/14.3/0.0/0.0
drayage-100-23	3/0/0	33.4	<b>0.2</b>	<b>9.0</b>	0.0	-7.2/33.3/52.4/0.0
drayage-25-23	3/0/0	<b>25.1</b>	0.2	<b>12.8</b>	0.0	15.2/0.0/-45.3/0.0
ds	0/0/0	-	-	-	-	-/-/-/-
dws008-01	0/0/3	82.5	42.4	707.9	182.8	-/-/-/-
eil33-2	2/1/0	53.4	<b>4.2</b>	<b>68.0</b>	<b>4.6</b>	-0.9/-66.7/-56.8/-91.3
eilA101-2	0/0/1	466.4	3460.9	688.0	4.0	-/-/-/-
enlight-hard	0/0/3	0.0	0.8	803.8	409.6	0.0/0.0/0.0/0.0
exp-1-500-5-5	3/0/0	<b>133.9</b>	0.1	<b>15.5</b>	0.0	-43.0/0.0/42.4/0.0
fast0507	3/0/0	23.8	<b>1.6</b>	1.0	0.0	0.0/-12.5/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>597.2</b>	<b>0.2</b>	<b>37.3</b>	<b>1.3</b>	-12.6/-50.0/-55.5/-100.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>18.1</b>	<b>0.7</b>	<b>7.5</b>	<b>0.0</b>	-29.3/81.6/85.9/100.0
fiber	3/0/0	173.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
fixnet6	3/0/0	<b>34.7</b>	0.1	31.0	1.0	-20.2/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	15.0	0.1	1.3	0.0	0.0/0.0/0.0/0.0
germanrr	0/3/0	2.6	<b>4.0</b>	<b>21.5</b>	<b>0.3</b>	-3.8/13.0/19.5/-100.0
gesa2	0/3/0	2.3	0.1	20.4	0.0	-8.7/0.0/0.0/0.0
gesa2-o	0/3/0	22.4	0.1	36.0	<b>1.9</b>	-6.2/0.0/-5.6/13.6
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.2	1.0	0.0	0.0/0.0/0.0/0.0
glass4	3/0/0	<b>338.3</b>	0.1	<b>72.7</b>	<b>29.9</b>	31.1/0.0/48.5/57.3
gmu-35-40	3/0/0	<b>2.5</b>	<b>0.3</b>	<b>120.0</b>	<b>29.2</b>	45.7/-33.3/-42.3/-71.9
gmu-35-50	3/0/0	<b>2.5</b>	0.1	<b>35.9</b>	<b>1.4</b>	-56.0/0.0/-63.0/-100.0
graph20-20-1rand	3/0/0	<b>16.1</b>	<b>3.8</b>	<b>14.3</b>	0.0	42.5/48.6/37.8/0.0
graphdraw-domain	0/3/0	<b>54.9</b>	0.1	<b>22.1</b>	<b>1.2</b>	-17.1/0.0/69.0/91.7
h80x6320d	3/0/0	<b>34.6</b>	1.4	33.3	2.2	-12.4/-7.1/0.0/0.0
harp2	3/0/0	12.0	0.1	<b>14.5</b>	0.0	-5.8/0.0/-10.3/0.0
highschool1-aigio	0/3/0	inf	<b>829.9</b>	<b>55.8</b>	<b>0.3</b>	0.0/-64.5/-47.1/50.0
hypothyroid-k1	3/0/0	0.0	31.4	1.0	0.0	0.0/-1.6/0.0/0.0
ic97p	0/0/3	<b>12.3</b>	<b>2.7</b>	875.6	211.1	20.6/18.2/16.3/5.5
ic97t	0/2/0	12.0	0.4	340.8	110.9	-/-/-/-
icir97p	0/0/3	20.3	<b>17.9</b>	1257.1	222.8	3.8/-24.6/-22.9/-40.3
icir97t	0/3/0	<b>12.8</b>	<b>1.9</b>	<b>136.5</b>	<b>75.1</b>	10.5/-10.5/14.8/24.5
irish-electricity	0/0/3	41.5	<b>996.0</b>	782.5	5.3	8.2/25.6/37.0/80.2
irp	3/0/0	<b>3.0</b>	<b>1.7</b>	<b>20.1</b>	<b>0.6</b>	-66.7/-47.1/-30.8/-100.0
istanbul-no-cutoff	3/0/0	24.9	<b>4.3</b>	<b>12.7</b>	0.0	-7.6/-23.3/-29.1/0.0
k1mushroom	3/0/0	18.2	26.1	1.0	0.0	0.0/-0.4/0.0/0.0
lectsched-5-obj	0/0/3	2526.0	<b>131.5</b>	1301.0	0.3	5.4/-34.7/-21.8/0.0
leo1	3/0/0	50.6	0.2	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	48.3	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>410.2</b>	<b>0.1</b>	<b>14.6</b>	<b>0.0</b>	39.2/80.0/84.4/100.0
lotsize	3/0/0	<b>220.6</b>	0.3	42.3	<b>7.6</b>	-71.5/0.0/9.2/16.5
mad	3/0/0	9829.7	0.1	15.3	0.0	-4.4/0.0/-8.5/0.0
manna81	0/3/0	1.1	0.1	2.6	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.27 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
map10	3/0/0	<b>66.2</b>	<b>26.4</b>	<b>8.0</b>	<b>0.0</b>	-54.7/58.4/80.0/100.0
map16715-04	3/0/0	<b>85.0</b>	<b>32.9</b>	<b>8.7</b>	<b>0.0</b>	4.7/69.3/81.2/100.0
markshare1	3/0/0	<b>58961.3</b>	0.1	<b>51.6</b>	<b>8.2</b>	-17.5/0.0/26.6/49.7
markshare2	3/0/0	<b>49263.2</b>	0.1	<b>53.0</b>	<b>8.3</b>	44.8/0.0/24.6/46.8
markshare-4-0	3/0/0	<b>25992.0</b>	0.1	<b>48.2</b>	<b>8.1</b>	-30.5/0.0/25.8/49.1
mas74	0/3/0	<b>41.6</b>	0.1	<b>7.2</b>	<b>0.0</b>	22.4/0.0/92.0/100.0
mas76	0/3/0	<b>14.0</b>	0.1	<b>4.6</b>	<b>0.0</b>	27.5/0.0/94.9/100.0
mc11	3/0/0	116.3	0.4	43.0	13.0	-8.6/0.0/-1.6/-5.4
mcsched	3/0/0	<b>23.7</b>	0.2	<b>4.3</b>	0.0	-48.1/0.0/-16.3/0.0
mik-250-20-75-4	0/3/0	<b>2.2</b>	0.1	<b>6.3</b>	<b>0.0</b>	96.4/0.0/83.6/100.0
milo-v12-6-r2-40-1	3/0/0	143.4	1.4	41.3	11.3	4.3/0.0/1.7/5.0
misc07	3/0/0	<b>46.3</b>	0.1	24.4	<b>0.6</b>	-30.7/0.0/-6.6/-50.0
mkc	0/3/0	70.8	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	0/0/0	-	-	-	-	-/-/-/-
modglob	3/0/0	<b>50.8</b>	0.1	<b>5.6</b>	<b>0.0</b>	-99.6/0.0/82.1/100.0
momentum1	0/2/1	259.7	<b>186.0</b>	1463.5	1280.7	4.9/-24.8/-34.8/-43.4
msc98-ip	0/3/0	<b>18.7</b>	<b>1.7</b>	<b>9.9</b>	0.0	-28.3/32.0/34.4/0.0
mushroom-best	0/3/0	<b>8.22e06</b>	<b>30.6</b>	<b>83.3</b>	<b>28.3</b>	15.0/-39.5/-43.6/-96.5
mzzv11	0/3/0	<b>19.7</b>	<b>1.7</b>	<b>12.6</b>	0.0	-21.8/41.4/40.6/0.0
mzzv42z	0/3/0	<b>18.8</b>	<b>1.1</b>	<b>5.6</b>	<b>0.0</b>	17.9/64.5/76.9/100.0
n2seq36q	3/0/0	<b>5.9</b>	<b>0.5</b>	<b>3.0</b>	0.0	28.9/-20.0/-33.3/0.0
n3div36	3/0/0	43.5	0.3	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>24.2</b>	<b>0.3</b>	20.4	0.0	26.7/-33.3/0.0/0.0
neos-1122047	3/0/0	0.6	0.3	1.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>4.9</b>	<b>1.9</b>	<b>3.6</b>	0.0	33.8/34.5/72.7/0.0
neos-1171737	3/0/0	<b>13.4</b>	<b>0.5</b>	<b>3.9</b>	0.0	-71.6/70.6/84.1/0.0
neos-1354092	0/3/0	15.1	<b>73.6</b>	<b>26.0</b>	0.0	7.4/27.5/23.3/0.0
neos-1445765	3/0/0	<b>16.5</b>	1.6	<b>7.6</b>	0.0	33.2/5.9/32.7/0.0
neos-1456979	0/1/2	<b>107.7</b>	<b>22.7</b>	373.5	60.1	35.2/34.2/33.2/30.0
neos-1582420	0/3/0	80.7	1.2	<b>132.4</b>	18.6	-7.8/-8.3/-15.4/2.1
neos-2657525-crna	0/3/0	1076.3	<b>0.1</b>	41.7	2.3	-6.2/83.3/62.0/67.6
neos-2746589-doon	0/0/3	49.2	221.8	685.7	269.5	-/-/-/-
neos-2978193-inde	3/0/0	<b>15.7</b>	0.1	<b>4.2</b>	0.0	44.1/0.0/-38.1/0.0
neos-2987310-joes	3/0/0	<b>0.5</b>	<b>13.1</b>	<b>57.2</b>	<b>14.3</b>	16.7/-11.5/-10.3/-19.6
neos-3004026-krka	0/0/2	0.0	86.2	1322.7	2.2	-/-/-/-
neos-3024952-loue	0/1/2	740.7	<b>37.8</b>	1112.6	26.8	6.5/10.0/11.4/-4.5
neos-3046615-murg	0/3/0	<b>33.1</b>	0.1	<b>15.0</b>	<b>0.0</b>	99.8/0.0/85.6/100.0
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/0	-	-	-	-	-/-/-/-
neos-3381206-awhea	0/0/3	4.9	<b>11.4</b>	1087.1	0.3	0.0/-22.8/-21.5/-100.0
neos-3402294-bobin	3/0/0	<b>420.4</b>	<b>27.7</b>	<b>19.9</b>	0.0	40.1/-65.3/-24.1/0.0
neos-3555904-turama	0/1/2	<b>4.3</b>	<b>2839.4</b>	508.3	94.2	48.8/-33.8/14.3/-1.8
neos-3627168-kasai	3/0/0	2.4	0.1	<b>20.4</b>	<b>0.0</b>	-8.3/0.0/25.0/100.0
neos-3656078-kumeu	0/0/0	-	-	-	-	-/-/-/-
neos-3754480-nidda	3/0/0	<b>33.0</b>	0.1	<b>10.7</b>	<b>0.0</b>	-53.6/0.0/84.3/100.0
neos-4300652-rahue	0/0/3	206.4	885.8	716.2	0.4	0.0/-2.3/6.0/-25.0
neos-4338804-snowy	0/3/0	1.29e05	<b>0.5</b>	<b>163.8</b>	<b>37.5</b>	0.0/28.6/15.8/18.5
neos-4387871-tavua	0/0/3	<b>677.1</b>	<b>14.5</b>	912.9	483.3	17.3/-35.9/-35.6/-40.2
neos-4413714-turia	3/0/0	<b>168.2</b>	<b>55.7</b>	<b>8.3</b>	<b>0.0</b>	99.3/89.2/90.7/100.0
neos-4532248-waihi	0/0/3	949.4	<b>720.5</b>	767.0	43.4	0.0/12.6/12.0/-6.7
neos-4647030-tutaki	3/0/0	<b>99.9</b>	<b>20.2</b>	<b>15.1</b>	0.0	-68.6/25.2/26.0/0.0
neos-4722843-widden	0/3/0	37.9	16.8	45.9	<b>7.9</b>	2.6/-0.6/5.6/15.1
neos-4738912-atrato	0/3/0	11.1	0.3	<b>13.4</b>	<b>0.3</b>	8.3/0.0/24.7/-100.0
neos-4763324-toguru	3/0/0	<b>50.6</b>	<b>57.0</b>	<b>8.0</b>	0.0	-39.3/-19.3/62.4/0.0
neos-4954672-berkel	3/0/0	<b>94.6</b>	0.1	<b>11.6</b>	<b>0.0</b>	-51.6/0.0/64.1/100.0
neos-5049753-cuanza	0/1/2	<b>57.2</b>	923.9	699.8	114.3	16.3/-9.4/-0.1/12.6
neos-5052403-cygnnet	3/0/0	0.3	70.0	2.0	0.0	0.0/2.2/0.0/0.0
neos-5093327-huahum	3/0/0	<b>47.9</b>	<b>5.6</b>	<b>35.8</b>	<b>4.2</b>	76.8/64.8/64.2/87.0
neos-5104907-jarama	0/0/0	-	-	-	-	-/-/-/-
neos-5107597-kakapo	1/2/0	38596.2	<b>21.6</b>	433.4	391.8	-7.6/-10.2/-5.5/-5.6
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-

(continued)

Table A.27 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-5188808-nattai	3/0/0	4474.0	<b>4.0</b>	<b>20.3</b>	0.0	-2.9/20.0/20.7/0.0
neos-5195221-niemur	3/0/0	897.7	<b>32.5</b>	<b>20.3</b>	0.0	5.8/-78.2/-43.8/0.0
neos-631710	3/0/0	173.9	1.6	1.0	0.0	0.0/0.0/0.0/0.0
neos-662469	0/3/0	1527.8	3.9	2.9	0.0	0.0/4.9/0.0/0.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	<b>0.4</b>	<b>0.9</b>	<b>2.3</b>	0.0	-100.0/18.2/23.3/0.0
neos-848589	3/0/0	<b>3.32e05</b>	<b>57.4</b>	<b>73.3</b>	<b>23.0</b>	-84.7/12.6/-10.6/-20.4
neos-860300	3/0/0	<b>55.0</b>	<b>0.5</b>	<b>10.5</b>	0.0	-34.4/-60.0/-61.9/0.0
neos-873061	3/0/0	52.2	54.2	31.3	1.3	5.8/-4.8/0.0/0.0
neos-911970	3/0/0	<b>244.8</b>	0.1	<b>18.0</b>	<b>0.0</b>	-29.5/0.0/65.4/100.0
neos-933966	3/0/0	<b>3.5</b>	<b>5.8</b>	<b>6.6</b>	0.0	97.2/-62.1/32.7/0.0
neos-950242	3/0/0	<b>17.6</b>	<b>31.8</b>	23.4	<b>0.0</b>	77.9/-34.6/-3.4/100.0
neos-957323	3/0/0	11.4	<b>2.4</b>	1.3	0.0	0.0/-20.8/0.0/0.0
neos-960392	3/0/0	<b>1.9</b>	<b>3.3</b>	<b>6.2</b>	0.0	-57.9/17.5/11.4/0.0
neos10	0/3/0	117.8	0.1	2.9	0.0	7.3/0.0/0.0/0.0
neos16	0/0/0	-	-	-	-	-/-/-/-
neos17	3/0/0	253.5	0.1	34.9	<b>2.7</b>	0.0/0.0/-9.2/-40.7
neos20	0/0/2	68.4	6.0	1298.4	41.0	-/-/-/-
neos5	3/0/0	<b>38.8</b>	0.1	<b>2.7</b>	0.0	-32.7/0.0/18.2/0.0
neos7	0/3/0	<b>16.4</b>	0.1	<b>7.0</b>	<b>0.0</b>	21.9/0.0/84.5/100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>41.2</b>	<b>6.9</b>	36.1	<b>0.0</b>	-26.0/-13.0/-1.7/100.0
netdiversion	3/0/0	<b>73.0</b>	<b>234.8</b>	<b>14.6</b>	0.0	19.3/-78.7/-33.6/0.0
nexp-150-20-8-5	3/0/0	142.4	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/1/2	<b>10.8</b>	<b>5.6</b>	728.8	208.8	13.6/30.9/27.4/2.5
nh97t	0/0/3	11.1	<b>12.8</b>	1265.8	284.4	0.9/-33.6/-28.5/-21.9
noswot	0/3/0	<b>5.6</b>	0.1	<b>5.8</b>	<b>0.0</b>	16.4/0.0/82.8/100.0
ns1116954	2/1/0	0.0	230.7	130.4	5.2	0.0/0.9/0.0/0.0
ns1208400	1/2/0	0.0	<b>182.7</b>	<b>353.2</b>	<b>0.4</b>	0.0/-47.0/-46.4/-100.0
ns1644855	3/0/0	<b>22.2</b>	<b>410.5</b>	<b>4.0</b>	<b>0.0</b>	-95.0/71.6/91.2/100.0
ns1760995	3/0/0	<b>37.8</b>	<b>76.5</b>	<b>17.6</b>	<b>0.0</b>	-50.5/75.0/78.0/100.0
ns1830653	2/1/0	<b>128.2</b>	<b>3.2</b>	139.1	14.6	47.1/52.2/66.0/80.4
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ixp	3/0/0	47.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	2.6	<b>0.1</b>	<b>3.0</b>	0.0	0.0/66.7/80.9/0.0
nursesched-medium-hint03	0/3/0	<b>1219.0</b>	<b>77.6</b>	<b>33.7</b>	<b>0.3</b>	-39.6/-82.0/-59.1/-100.0
nursesched-sprint02	0/3/0	100.3	<b>2.8</b>	<b>13.6</b>	0.0	-6.3/-14.3/-14.7/0.0
nw04	3/0/0	<b>15.8</b>	<b>1.3</b>	<b>7.8</b>	0.0	28.8/38.1/40.0/0.0
opm2-z10-s4	3/0/0	94.2	64.4	1.0	0.0	0.0/6.5/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	0.1	<b>4.0</b>	<b>0.0</b>	100.0/0.0/88.9/100.0
p200x1188c	3/0/0	3.9	0.1	31.0	1.0	0.0/0.0/0.0/0.0
p2756	0/3/0	67.4	0.1	<b>7.0</b>	0.0	0.4/0.0/-28.6/0.0
peg-solitaire-a3	0/0/3	0.0	2112.1	1189.6	147.9	0.0/-1.4/-15.3/-68.0
pg	3/0/0	<b>18.9</b>	0.1	<b>9.7</b>	<b>0.0</b>	-18.0/0.0/81.2/100.0
pg5-34	3/0/0	<b>6.3</b>	<b>0.1</b>	<b>6.8</b>	<b>0.0</b>	11.3/50.0/86.9/100.0
physiciansched3-3	3/0/0	<b>29.8</b>	<b>527.6</b>	<b>56.1</b>	<b>1.9</b>	-58.7/15.2/-37.1/-63.2
physiciansched6-2	0/3/0	73.3	<b>31.1</b>	<b>222.8</b>	<b>3.0</b>	-7.4/17.9/16.3/-43.3
piperout-08	0/0/3	<b>50.3</b>	<b>35.4</b>	1064.4	9.5	-36.6/-19.5/-18.2/4.0
piperout-27	0/0/3	<b>47.2</b>	43.4	1051.4	3.7	-21.4/-6.7/-8.4/32.7
pk1	3/0/0	1675.2	0.1	<b>35.0</b>	<b>1.6</b>	-8.4/0.0/40.4/82.0
pp08a	3/0/0	55.9	0.1	15.6	0.0	-3.6/0.0/0.0/0.0
pp08aCUTS	3/0/0	<b>19.4</b>	0.1	<b>15.1</b>	0.0	26.5/0.0/-20.5/0.0
proteindesign121hz512p9	0/3/0	3.3	<b>5.5</b>	30.7	0.8	-3.0/96.2/93.9/92.5
proteindesign122trx11p8	0/2/1	1.1	324.5	132.3	5.8	-/-/-/-
protfold	3/0/0	63.0	<b>4.5</b>	<b>19.4</b>	<b>0.0</b>	5.3/30.8/26.8/100.0
qap10	3/0/0	0.0	11.3	2.0	0.0	0.0/5.0/0.0/0.0
qiu	3/0/0	1517.0	0.1	3.3	0.0	0.9/0.0/0.0/0.0
rB10-011000	3/0/0	264.5	0.4	27.2	<b>0.3</b>	-9.2/0.0/-7.0/-100.0
rB10-011001	3/0/0	218.6	0.4	27.2	<b>0.3</b>	-6.6/0.0/-3.3/-100.0
rB11-010000	3/0/0	269.8	1.1	26.7	0.3	6.8/8.3/9.8/0.0
rB11-110001	3/0/0	<b>159.0</b>	3.5	<b>24.5</b>	0.0	11.1/-2.9/16.4/0.0

(continued)

Table A.27 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
rB12-111111	0/2/1	<b>88.7</b>	<b>24.5</b>	460.0	9.5	-19.5/19.4/4.5/-9.5
rC10-001000	3/0/0	<b>218.8</b>	0.1	27.4	<b>0.0</b>	24.1/0.0/3.2/100.0
rC10-100001	2/1/0	456.9	<b>2.7</b>	106.4	<b>1.9</b>	-4.5/-11.1/0.8/-10.5
rC11-010100	3/0/0	347.0	0.3	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>579.0</b>	<b>5.8</b>	<b>69.1</b>	<b>2.6</b>	-49.2/-34.5/-57.0/-69.2
rC12-111100	3/0/0	194.9	0.4	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>581.7</b>	<b>4.0</b>	<b>207.1</b>	<b>19.2</b>	80.2/13.0/16.2/29.7
radiationm40-10-02	0/0/3	1550.2	91.2	1265.2	9.9	0.0/-3.1/-7.2/40.7
rail01	3/0/0	36.1	1661.0	<b>13.3</b>	<b>0.0</b>	1.4/6.6/58.6/100.0
rail02	3/0/0	<b>3.0</b>	<b>2387.8</b>	<b>4.9</b>	0.0	50.8/-25.1/-18.4/0.0
rail507	3/0/0	23.8	2.2	1.0	0.0	0.0/-4.5/0.0/0.0
ran14x18-disj-8	3/0/0	<b>24.9</b>	0.1	23.3	<b>0.6</b>	-33.3/0.0/-2.1/-50.0
rd-rplusc-21	0/0/3	101.8	<b>161.0</b>	954.5	497.0	-0.3/-20.0/-16.6/-20.7
reblock115	0/3/0	<b>14.0</b>	3.9	<b>26.0</b>	<b>1.7</b>	-17.1/-2.6/37.5/10.5
rmatr100-p10	3/0/0	<b>2.2</b>	<b>0.7</b>	<b>4.3</b>	0.0	92.5/-14.3/-46.5/0.0
rmatr200-p5	3/0/0	19.9	<b>26.5</b>	<b>6.0</b>	0.0	-2.0/-32.5/-66.7/0.0
rocl-4-11	0/0/3	<b>48.1</b>	<b>26.0</b>	944.7	36.4	30.4/-18.8/-16.3/-15.9
rocll-5-11	0/0/3	<b>99.4</b>	74.1	854.6	85.9	-12.0/-5.1/-7.1/2.9
roi2alpha3n4	3/0/0	<b>59.2</b>	<b>6.3</b>	<b>7.0</b>	<b>0.0</b>	-12.3/77.7/79.2/100.0
roi5alpha10n8	3/0/0	<b>56.6</b>	<b>80.8</b>	<b>7.0</b>	0.0	15.1/82.4/76.4/0.0
roll3000	0/3/0	35.0	<b>0.5</b>	<b>38.7</b>	<b>2.0</b>	-4.3/28.6/22.6/53.5
rout	0/3/0	34.6	0.1	<b>25.9</b>	<b>0.4</b>	2.3/0.0/23.8/69.2
s100	3/0/0	<b>4.4</b>	<b>334.2</b>	<b>9.3</b>	0.0	-31.8/-15.8/-29.0/0.0
s250r10	3/0/0	0.1	61.8	2.0	0.0	0.0/2.8/0.0/0.0
satellites2-40	3/0/0	<b>206.6</b>	<b>2254.2</b>	37.2	<b>3.0</b>	37.4/-66.0/2.9/33.3
satellites2-60-fs	3/0/0	<b>344.2</b>	<b>880.7</b>	42.2	5.8	13.5/-60.2/-4.3/-5.2
savsched1	3/0/0	<b>11.3</b>	119.6	<b>6.3</b>	0.0	-45.1/-5.1/44.2/0.0
sct2	3/0/0	<b>21.5</b>	<b>0.1</b>	<b>4.6</b>	0.0	-38.6/50.0/79.4/0.0
set1ch	3/0/0	<b>22.8</b>	0.1	31.0	1.0	59.3/0.0/0.0/0.0
seymour	3/0/0	12.3	<b>1.1</b>	1.0	0.0	0.0/-18.2/0.0/0.0
seymour1	3/0/0	<b>1.7</b>	<b>2.3</b>	<b>3.0</b>	0.0	-41.2/56.6/62.5/0.0
sing326	3/0/0	<b>51.6</b>	<b>10.0</b>	<b>8.4</b>	<b>0.0</b>	-24.2/53.5/78.6/100.0
sing44	3/0/0	<b>32.5</b>	<b>9.5</b>	<b>4.6</b>	<b>0.0</b>	-64.6/46.0/87.5/100.0
snp-02-004-104	0/3/0	<b>18.0</b>	42.3	33.0	<b>1.0</b>	-86.1/2.1/0.9/37.5
sorrell3	3/0/0	73.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.3	1.3	0.0/0.0/0.0/0.0
sp97ar	3/0/0	24.4	51.3	2.2	0.0	-6.1/-7.4/0.0/0.0
sp98ar	3/0/0	29.0	41.9	1.0	0.0	0.0/-2.1/0.0/0.0
splice1k1	3/0/0	99.0	130.3	<b>9.0</b>	0.0	-0.4/-6.1/30.8/0.0
square41	0/3/0	6.7	884.7	11.0	0.0	0.0/-9.6/-9.1/0.0
square47	0/3/0	<b>7.9</b>	<b>1368.6</b>	<b>13.3</b>	0.0	35.8/12.1/-17.3/0.0
supportcase10	3/0/0	<b>42.9</b>	<b>268.8</b>	<b>4.0</b>	0.0	78.0/77.0/69.2/0.0
supportcase12	0/3/0	<b>7.0</b>	<b>15.3</b>	<b>4.2</b>	<b>0.0</b>	-28.6/49.8/83.1/100.0
supportcase18	3/0/0	77.1	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>26.2</b>	0.1	<b>7.0</b>	<b>0.0</b>	42.7/0.0/92.2/100.0
supportcase33	0/3/0	<b>65.9</b>	<b>11.1</b>	<b>125.9</b>	<b>21.5</b>	18.5/62.9/45.4/73.5
supportcase40	3/0/0	<b>43.1</b>	<b>4.0</b>	<b>7.7</b>	0.0	-59.2/34.4/53.6/0.0
supportcase42	0/3/0	16.9	<b>7.2</b>	<b>5.3</b>	0.0	-7.1/16.3/50.5/0.0
supportcase6	3/0/0	<b>0.5</b>	<b>29.8</b>	<b>5.6</b>	0.0	81.5/68.8/61.4/0.0
supportcase7	3/0/0	<b>62.2</b>	<b>89.5</b>	<b>10.3</b>	0.0	-25.4/-26.5/57.8/0.0
swath	0/3/0	<b>178.7</b>	19.2	168.6	52.7	11.6/4.0/8.8/6.1
swath1	1/2/0	68.1	<b>4.6</b>	<b>74.0</b>	<b>20.7</b>	2.0/-15.2/-16.2/-21.3
swath3	3/0/0	11.5	<b>2.6</b>	<b>49.0</b>	<b>7.6</b>	-1.7/29.7/17.5/50.6
t1717	3/0/0	222.0	250.1	55.8	0.3	-8.2/4.8/3.8/0.0
tbfp-network	3/0/0	<b>42.6</b>	<b>125.2</b>	<b>13.6</b>	0.0	26.6/-42.8/-48.5/0.0
thor50dday	3/0/0	<b>303.3</b>	5.5	25.3	<b>1.9</b>	-15.0/-3.6/-3.2/-10.5
timtab1	0/3/0	72.4	0.1	<b>74.8</b>	<b>16.5</b>	3.9/0.0/28.8/50.2
timtab2	0/3/0	88.1	<b>1.9</b>	518.3	196.6	-2.5/24.0/12.8/11.6
tr12-30	3/0/0	<b>54.6</b>	0.1	32.6	<b>2.0</b>	25.9/0.0/-4.9/-50.0
traininstance2	0/0/3	345.5	24.7	1231.8	71.8	0.0/0.8/0.0/0.0

(continued)

Table A.27 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
traininstance6	0/1/2	<b>1274.0</b>	<b>17.1</b>	1240.4	85.9	-52.3/-50.9/-49.0/-43.3
trento1	3/0/0	12.1	<b>61.4</b>	<b>7.8</b>	0.0	4.0/-49.3/-57.7/0.0
triptim1	0/3/0	0.1	<b>116.0</b>	<b>6.2</b>	0.0	0.0/10.7/-11.3/0.0
uccase12	3/0/0	<b>4.0</b>	<b>13.3</b>	<b>17.2</b>	0.0	-100.0/23.6/16.1/0.0
uccase9	3/0/0	<b>317.3</b>	<b>10.4</b>	25.4	2.3	67.6/76.8/88.4/97.3
uct-subprob	3/0/0	<b>18.4</b>	0.1	7.0	0.0	-24.5/0.0/4.1/0.0
unitcal-7	0/2/1	49.0	<b>195.5</b>	1205.5	283.9	-5.3/-21.5/-18.9/-36.6
var-smallemercy-m6j6	3/0/0	<b>22.5</b>	<b>9.0</b>	<b>5.3</b>	<b>0.0</b>	61.2/63.0/92.1/100.0
vpm2	3/0/0	31.8	0.1	<b>22.0</b>	<b>0.3</b>	9.1/0.0/29.0/70.0
wachplan	0/3/0	0.0	<b>0.6</b>	<b>13.2</b>	0.0	0.0/53.8/45.7/0.0
Geom. means		(262 instances)	(224 instances)			
FP		42.3	6.7	17.2	1.3	
FP+(c,Δ)		<b>40.6</b>	<b>6.3</b>	<b>12.3</b>	<b>0.7</b>	

Table A.28.: Performance of FP+(3,sv,g) with CPLEX

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	0/2/1	<b>5.2</b>	<b>14.5</b>	565.7	66.9	25.7/-88.3/-91.6/-100.0
30n20b8	0/1/2	<b>194.3</b>	18.2	1073.8	219.3	12.6/8.5/6.6/17.8
50v-10	0/3/0	<b>131.4</b>	0.2	<b>20.4</b>	<b>0.0</b>	-12.9/0.0/30.1/100.0
CMS750-4	3/0/0	<b>67.8</b>	<b>6.6</b>	<b>137.2</b>	<b>23.0</b>	-11.7/-48.5/-52.5/-40.4
a1c1s1	3/0/0	<b>27.4</b>	0.2	32.3	<b>2.3</b>	23.2/0.0/-1.9/-30.4
academictimetablesmall	0/0/3	inf	<b>1842.6</b>	1031.5	0.3	0.0/15.5/1.2/-100.0
aflow30a	3/0/0	<b>154.6</b>	0.1	<b>66.2</b>	<b>16.3</b>	41.7/0.0/-41.2/-69.9
aflow40b	2/1/0	226.9	<b>0.5</b>	<b>99.2</b>	<b>27.7</b>	9.6/-60.0/-55.3/-76.5
air04	3/0/0	<b>0.7</b>	19.6	<b>11.9</b>	0.0	22.2/9.3/-19.3/0.0
air05	3/0/0	<b>1.8</b>	<b>4.5</b>	<b>7.3</b>	0.0	-16.7/-17.8/-41.1/0.0
app1-1	3/0/0	<b>33.3</b>	0.2	36.0	<b>3.3</b>	-100.0/0.0/-0.8/23.3
app1-2	3/0/0	45.5	<b>11.5</b>	<b>55.0</b>	<b>16.3</b>	-5.3/-24.3/-26.4/-50.9
arki001	0/2/1	2.3	<b>7.9</b>	639.1	173.2	-8.7/-17.7/-41.5/-53.3
assign1-5-8	3/0/0	<b>1.1</b>	0.1	<b>24.0</b>	0.0	31.2/0.0/-15.8/0.0
atlanta-ip	0/3/0	<b>44.2</b>	<b>55.9</b>	<b>152.9</b>	<b>22.7</b>	-26.5/-17.9/-69.3/-96.9
b1c1s1	3/0/0	<b>145.4</b>	0.2	34.0	4.0	15.4/0.0/-0.9/-10.0
bab2	0/0/3	59.8	1379.6	1405.6	213.7	-/-/-/-
bab6	0/0/3	<b>37.9</b>	<b>511.4</b>	963.9	70.7	-21.1/-32.1/-57.5/-1.8
beasleyC3	3/0/0	11.7	0.1	35.7	<b>5.6</b>	4.9/0.0/-2.0/-14.3
binkar10-1	3/0/0	3.9	0.1	<b>4.9</b>	0.0	0.0/0.0/18.3/0.0
blp-ar98	3/0/0	<b>64.2</b>	<b>1.4</b>	<b>13.3</b>	0.0	-12.6/-14.3/-19.5/0.0
blp-ic98	3/0/0	21.2	1.0	7.0	0.0	1.9/-10.0/-5.7/0.0
bnatt400	0/0/0	-	-	-	-	-/-/-/-
bppc4-08	3/0/0	<b>24.6</b>	0.4	61.7	8.3	52.0/0.0/-0.2/7.8
brazil3	0/3/0	<b>286.4</b>	29.2	24.3	0.0	49.9/-4.8/2.4/0.0
buildingenergy	0/1/0	0.6	3155.3	11.0	0.0	-/-/-/-
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	inf	1.7	31.3	1.3	0.0/0.0/0.0/0.0
chromaticindex1024-7	3/0/0	0.0	<b>6.3</b>	2.0	0.0	0.0/10.0/0.0/0.0
chromaticindex512-7	3/0/0	0.0	3.2	2.0	0.0	0.0/-6.3/0.0/0.0
cmflsp50-24-8-8	2/0/1	<b>18.5</b>	<b>65.8</b>	293.4	79.7	13.1/72.8/76.3/77.2
co-100	3/0/0	346.5	<b>2.8</b>	<b>14.3</b>	0.0	0.1/28.2/28.1/0.0
cod105	3/0/0	100.0	2.0	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	3990.8	16.7	25.9	0.0	0.3/8.2/0.0/0.0
comp21-2idx	0/3/0	341.5	<b>14.8</b>	<b>26.7</b>	0.0	1.7/14.0/-20.6/0.0
cost266-UUE	3/0/0	37.1	0.4	28.6	0.3	-4.3/0.0/-5.2/0.0
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/0/3	<b>65.2</b>	<b>9.8</b>	1506.5	497.5	29.8/-57.1/-48.6/-66.3
csched008	0/3/0	8.7	<b>2.5</b>	<b>586.1</b>	<b>188.4</b>	-3.4/-56.0/-61.8/-71.4
cvs16r128-89	3/0/0	97.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.28 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
dano3-3	3/0/0	0.0	<b>40.3</b>	<b>16.6</b>	0.0	0.0/14.4/-12.7/0.0
dano3-5	3/0/0	<b>0.1</b>	<b>389.9</b>	<b>40.7</b>	<b>4.8</b>	50.0/-64.3/-27.3/-83.3
dano3mip	3/0/0	<b>12.4</b>	1222.6	72.0	<b>15.9</b>	23.0/4.8/-2.8/11.2
danooint	1/2/0	27.8	<b>0.7</b>	<b>156.7</b>	<b>60.4</b>	0.0/30.0/-44.7/-54.3
disctom	3/0/0	0.0	<b>3.6</b>	<b>4.0</b>	0.0	0.0/-22.2/-25.0/0.0
drayage-100-23	3/0/0	<b>47.2</b>	0.3	17.9	0.0	-34.3/0.0/5.3/0.0
drayage-25-23	3/0/0	<b>53.5</b>	<b>0.4</b>	<b>24.7</b>	<b>0.3</b>	-44.7/-50.0/-71.7/-100.0
ds	0/0/0	-	-	-	-	-/-/-/-
dws008-01	0/0/3	54.2	31.2	731.6	188.0	-/-/-/-
eil33-2	0/3/0	<b>36.8</b>	<b>17.0</b>	<b>279.2</b>	<b>63.0</b>	30.4/-91.8/-89.5/-99.4
eilA101-2	0/1/1	201.8	2210.2	475.8	7.7	-/-/-/-
enlight-hard	0/0/3	0.0	<b>1.0</b>	849.9	256.0	0.0/-20.0/-5.4/37.5
exp-1-500-5-5	3/0/0	<b>51.7</b>	0.1	27.2	<b>0.3</b>	32.2/0.0/-1.1/-100.0
fast0507	3/0/0	23.8	<b>1.9</b>	1.0	0.0	0.0/-26.3/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>1062.0</b>	0.1	<b>22.4</b>	0.0	-50.8/0.0/-25.9/0.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>11.2</b>	<b>4.4</b>	56.0	5.3	12.5/-13.6/-4.8/-7.5
fiber	3/0/0	173.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
fixnet6	3/0/0	25.2	0.1	31.0	1.0	9.0/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	15.0	0.1	1.3	0.0	0.0/0.0/0.0/0.0
germanrr	0/3/0	<b>3.6</b>	<b>8.8</b>	<b>48.2</b>	<b>7.0</b>	-30.6/-47.7/-44.6/-100.0
gesa2	0/3/0	2.1	0.1	20.4	0.0	0.0/0.0/0.0/0.0
gesa2-o	0/3/0	<b>16.4</b>	0.1	<b>39.3</b>	<b>2.8</b>	21.9/0.0/-13.5/-21.4
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.2	1.0	0.0	0.0/0.0/0.0/0.0
glass4	3/0/0	<b>433.8</b>	<b>0.2</b>	<b>179.1</b>	74.8	11.6/-50.0/-21.2/-6.3
gmu-35-40	3/0/0	<b>1.6</b>	<b>0.1</b>	<b>54.4</b>	<b>7.1</b>	65.2/50.0/21.4/13.4
gmu-35-50	3/0/0	1.2	0.1	<b>30.5</b>	<b>2.9</b>	-8.3/0.0/-56.4/-100.0
graph20-20-1rand	3/0/0	<b>11.1</b>	<b>27.1</b>	<b>32.6</b>	<b>0.3</b>	60.4/-72.7/-29.4/-100.0
graphdraw-domain	0/3/0	<b>62.8</b>	<b>0.2</b>	<b>131.1</b>	<b>43.8</b>	-27.5/-50.0/-45.7/-66.9
h80x6320d	3/0/0	30.3	1.3	33.3	2.2	0.0/0.0/0.0/0.0
harp2	3/0/0	11.9	0.1	12.7	0.0	-5.0/0.0/2.3/0.0
highschool1-aigio	0/3/0	inf	<b>603.7</b>	<b>78.7</b>	<b>2.2</b>	0.0/-51.1/-62.5/-72.7
hypothyroid-k1	3/0/0	0.0	32.9	1.0	0.0	0.0/-6.1/0.0/0.0
ic97p	0/0/3	14.9	<b>2.9</b>	926.0	308.9	3.9/12.1/11.5/-27.6
ic97t	0/1/0	14.8	0.9	776.0	353.0	-/-/-/-
icir97p	0/0/3	19.9	13.0	855.3	204.2	5.7/3.7/11.8/-34.9
icir97t	0/2/1	14.4	<b>6.9</b>	532.7	315.1	-0.7/-75.4/-69.9/-68.4
irish-electricity	0/0/3	<b>34.3</b>	<b>913.6</b>	917.4	6.3	24.1/31.8/26.1/76.5
irp	3/0/0	<b>1.4</b>	<b>1.6</b>	<b>21.3</b>	<b>0.4</b>	-28.6/-43.8/-34.7/-100.0
istanbul-no-cutoff	3/0/0	<b>18.9</b>	<b>4.0</b>	<b>11.0</b>	0.0	17.8/-17.5/-18.2/0.0
k1mushroom	3/0/0	18.2	25.9	1.0	0.0	0.0/0.4/0.0/0.0
lectsched-5-obj	0/0/3	2588.3	81.7	979.0	0.0	3.1/4.9/3.7/100.0
leo1	3/0/0	50.6	<b>0.1</b>	1.0	0.0	0.0/50.0/0.0/0.0
leo2	3/0/0	48.3	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>306.3</b>	0.5	92.9	<b>24.1</b>	54.6/0.0/0.4/39.1
lotsize	3/0/0	61.5	0.3	47.6	9.3	2.1/0.0/-2.1/-2.2
mad	3/0/0	<b>6498.4</b>	0.1	14.6	0.0	30.8/0.0/-4.1/0.0
manna81	0/3/0	1.1	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>24.7</b>	<b>77.4</b>	<b>65.5</b>	<b>17.6</b>	17.7/-18.0/-38.8/-73.9
map16715-04	3/0/0	<b>51.2</b>	<b>80.0</b>	<b>55.5</b>	<b>11.4</b>	42.6/25.4/-16.6/-21.9
markshare1	3/0/0	43976.5	0.1	<b>78.2</b>	16.0	9.6/0.0/-10.1/1.8
markshare2	3/0/0	85954.0	0.1	<b>86.3</b>	<b>17.6</b>	3.6/0.0/-18.5/-11.4
markshare-4-0	3/0/0	<b>28947.2</b>	0.1	<b>76.9</b>	<b>19.0</b>	-37.6/0.0/-15.5/-16.3
mas74	0/3/0	55.9	0.1	90.0	<b>9.0</b>	-4.1/0.0/0.0/38.4
mas76	0/3/0	<b>41.7</b>	0.1	90.0	<b>12.2</b>	-53.7/0.0/0.8/43.3
mc11	3/0/0	102.4	0.4	42.3	12.3	3.7/0.0/0.0/0.0
mcsched	3/0/0	<b>23.2</b>	0.2	3.6	0.0	-47.0/0.0/0.0/0.0
mik-250-20-75-4	0/3/0	<b>93.6</b>	0.1	<b>15.1</b>	<b>0.9</b>	-34.7/0.0/60.6/80.0
milo-v12-6-r2-40-1	3/0/0	<b>121.7</b>	1.5	42.3	12.3	18.8/-6.7/-0.7/-3.3

(continued)



Table A.28 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
misc07	3/0/0	<b>38.0</b>	0.1	<b>27.7</b>	<b>0.4</b>	-15.5/0.0/-17.7/-25.0
mkc	0/3/0	70.8	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	0/0/0	-	-	-	-	-/-/-/-
modglob	3/0/0	0.2	0.1	31.3	1.3	0.0/0.0/0.0/0.0
momentum1	0/0/3	<b>389.1</b>	130.4	904.8	547.6	-29.8/6.7/5.2/24.5
msc98-ip	0/3/0	14.3	<b>3.0</b>	<b>22.1</b>	0.0	-6.3/-16.7/-31.7/0.0
mushroom-best	0/3/0	<b>1.12e07</b>	<b>30.5</b>	<b>65.4</b>	<b>1.6</b>	-13.7/-39.3/-28.1/-37.5
mzzv11	0/3/0	<b>17.4</b>	2.9	20.8	0.0	-11.5/0.0/1.9/0.0
mzzv42z	0/3/0	21.7	2.8	<b>18.6</b>	<b>0.0</b>	5.2/9.7/23.1/100.0
n2seq36q	3/0/0	8.3	0.4	2.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	43.5	0.3	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>28.4</b>	<b>0.3</b>	20.4	0.0	13.9/-33.3/0.0/0.0
neos-1122047	3/0/0	0.6	0.3	1.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>0.7</b>	2.7	<b>17.6</b>	0.0	90.5/6.9/-25.0/0.0
neos-1171737	3/0/0	4.0	<b>2.0</b>	23.8	0.0	-5.0/-15.0/3.3/0.0
neos-1354092	0/3/0	<b>12.1</b>	<b>116.8</b>	<b>44.3</b>	0.0	25.8/-13.1/-23.5/0.0
neos-1445765	3/0/0	<b>7.8</b>	1.7	10.7	0.0	68.4/0.0/5.3/0.0
neos-1456979	0/3/0	<b>121.1</b>	<b>19.7</b>	451.9	97.1	27.1/42.9/19.1/-11.5
neos-1582420	0/2/1	<b>99.7</b>	<b>3.8</b>	494.7	97.4	-25.4/-71.1/-77.4/-80.5
neos-2657525-crna	0/3/0	1090.8	<b>0.1</b>	62.1	3.9	-7.4/83.3/43.4/45.1
neos-2746589-doon	0/0/2	30.1	199.0	699.5	271.5	-/-/-/-
neos-2978193-inde	3/0/0	28.1	0.1	2.6	0.0	0.0/0.0/0.0/0.0
neos-2987310-joes	3/0/0	<b>0.3</b>	12.1	53.4	<b>8.4</b>	50.0/-4.1/-3.9/27.0
neos-3004026-krka	0/0/2	0.0	111.3	1633.2	1.4	-/-/-/-
neos-3024952-loue	0/0/3	<b>941.0</b>	<b>63.7</b>	1385.7	0.9	-15.9/-34.1/-9.4/96.5
neos-3046615-murg	0/3/0	<b>1581.6</b>	0.1	<b>91.0</b>	<b>60.0</b>	88.4/0.0/12.6/23.0
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	72.4	532.9	862.4	212.9	-/-/-/-
neos-3381206-awhea	0/0/3	<b>2.5</b>	<b>18.1</b>	1192.5	3.6	49.0/-51.4/-28.5/-100.0
neos-3402294-bobin	3/0/0	<b>390.7</b>	<b>12.5</b>	<b>31.9</b>	<b>0.4</b>	44.3/-23.2/-52.7/-100.0
neos-3555904-turama	0/0/3	<b>4.3</b>	<b>731.5</b>	719.8	52.0	48.8/61.1/-17.6/43.8
neos-3627168-kasai	3/0/0	<b>1.8</b>	0.1	27.2	0.3	18.2/0.0/0.0/0.0
neos-3656078-kumeu	0/0/0	-	-	-	-	-/-/-/-
neos-3754480-nidda	3/0/0	<b>6.3</b>	<b>0.1</b>	67.0	<b>10.3</b>	58.8/0.0/1.5/28.0
neos-4300652-rahue	0/1/2	197.4	<b>528.9</b>	375.6	0.3	4.4/38.9/50.7/0.0
neos-4338804-snowy	0/3/0	<b>65103.6</b>	0.7	195.2	50.3	49.5/0.0/-0.3/-8.5
neos-4387871-tavua	0/1/2	<b>982.1</b>	<b>12.6</b>	873.4	485.2	-16.7/-26.2/-32.7/-40.4
neos-4413714-turia	3/0/0	<b>543.3</b>	489.6	86.2	<b>14.4</b>	97.8/4.9/3.5/-12.5
neos-4532248-waihi	0/0/3	949.4	760.5	892.3	85.1	0.0/7.8/-2.3/-52.4
neos-4647030-tutaki	3/0/0	<b>41.0</b>	<b>34.2</b>	<b>26.0</b>	0.0	-23.4/-21.1/-21.5/0.0
neos-4722843-widden	0/3/0	<b>192.8</b>	15.4	46.4	<b>7.1</b>	-79.8/7.8/4.5/23.7
neos-4738912-atrato	0/3/0	<b>7.7</b>	0.3	<b>22.4</b>	0.0	36.4/0.0/-20.5/0.0
neos-4763324-toguru	3/0/0	<b>34.9</b>	47.3	22.0	0.0	-12.0/-2.7/-3.2/0.0
neos-4954672-berkel	3/0/0	<b>40.9</b>	0.1	35.3	<b>3.3</b>	10.7/0.0/-8.5/-39.4
neos-5049753-cuanza	0/0/3	<b>47.7</b>	<b>1449.9</b>	902.1	111.0	30.2/-42.3/-22.5/15.1
neos-5052403-cygnnet	3/0/0	<b>0.2</b>	73.6	<b>2.3</b>	0.0	33.3/-2.7/-13.0/0.0
neos-5093327-huahum	3/0/0	<b>24.9</b>	<b>10.4</b>	<b>72.9</b>	<b>23.3</b>	87.9/34.6/27.0/27.6
neos-5104907-jarama	0/0/0	-	-	-	-	-/-/-/-
neos-5107597-kakapo	0/2/1	<b>11476.2</b>	<b>30.4</b>	648.5	587.7	67.8/-36.2/-36.9/-37.1
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	4392.2	<b>3.8</b>	23.7	0.0	-1.1/24.0/7.4/0.0
neos-5195221-niemur	3/0/0	<b>3411.8</b>	<b>9.0</b>	<b>14.6</b>	0.0	-72.1/-21.1/-21.9/0.0
neos-631710	3/0/0	173.9	1.6	1.0	0.0	0.0/0.0/0.0/0.0
neos-662469	0/3/0	1574.2	4.2	2.9	0.0	-2.9/-2.4/0.0/0.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	1.0	<b>2.6</b>	0.0	0.0/9.1/13.3/0.0
neos-848589	3/0/0	<b>29982.3</b>	64.9	70.7	20.3	40.8/1.2/-7.4/-9.9
neos-860300	3/0/0	36.1	<b>0.3</b>	<b>5.0</b>	0.0	0.0/-33.3/-20.0/0.0
neos-873061	3/0/0	57.7	49.1	31.3	1.3	-4.0/4.8/0.0/0.0
neos-911970	3/0/0	180.5	0.1	53.0	4.6	-4.4/0.0/-1.9/6.1
neos-933966	3/0/0	<b>25.0</b>	<b>1.6</b>	<b>6.3</b>	0.0	79.7/27.3/35.7/0.0

(continued)

Table A.28 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-950242	2/1/0	<b>63.4</b>	<b>35.2</b>	<b>55.2</b>	<b>4.1</b>	20.6/-40.9/-59.1/-90.2
neos-957323	3/0/0	11.4	1.8	1.3	0.0	0.0/5.3/0.0/0.0
neos-960392	3/0/0	<b>3.1</b>	<b>6.9</b>	7.6	0.0	-74.2/-42.0/-7.9/0.0
neos10	0/3/0	127.1	0.1	2.9	0.0	0.0/0.0/0.0/0.0
neos16	0/0/2	2.3	6.1	1141.0	5.7	-/-/-/-
neos17	3/0/0	253.5	0.1	32.0	1.6	0.0/0.0/-0.9/0.0
neos20	0/0/3	75.1	7.0	1114.3	60.8	-/-/-/-
neos5	3/0/0	<b>29.5</b>	0.1	3.3	0.0	-11.5/0.0/0.0/0.0
neos7	0/3/0	<b>6.0</b>	0.1	<b>37.5</b>	<b>2.8</b>	71.4/0.0/17.2/55.6
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>24.2</b>	<b>5.1</b>	32.7	<b>0.0</b>	20.7/15.0/7.9/100.0
netdiversion	3/0/0	<b>130.5</b>	51.4	<b>14.9</b>	0.0	-30.7/-2.9/-34.9/0.0
nexp-150-20-8-5	3/0/0	142.4	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	<b>10.2</b>	<b>7.0</b>	945.4	286.8	18.4/13.6/5.8/-25.3
nh97t	0/0/3	<b>12.5</b>	9.2	875.1	201.2	-10.4/-7.6/3.4/9.4
noswot	0/3/0	<b>4.9</b>	0.1	34.0	<b>1.3</b>	26.9/0.0/-0.6/-23.1
ns1116954	0/2/1	0.0	<b>581.2</b>	581.5	14.7	0.0/-59.9/-77.6/-64.6
ns1208400	0/2/1	0.0	<b>331.2</b>	746.8	2.1	0.0/-70.7/-74.7/-100.0
ns1644855	3/0/0	<b>8.7</b>	1469.3	<b>52.3</b>	<b>8.3</b>	-87.4/-1.8/-13.6/-31.3
ns1760995	3/0/0	<b>24.0</b>	<b>238.9</b>	87.4	<b>2.6</b>	-22.1/22.1/-8.6/13.3
ns1830653	0/0/3	<b>296.5</b>	<b>9.9</b>	885.1	115.1	-18.3/-32.3/-53.8/-35.4
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ixp	3/0/0	47.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	2.6	0.3	15.7	0.0	0.0/0.0/0.0/0.0
nursesched-medium-hint03	0/3/0	768.3	<b>17.4</b>	<b>21.0</b>	0.0	-4.1/-19.5/-34.3/0.0
nursesched-sprint02	0/3/0	<b>138.0</b>	2.3	<b>12.9</b>	0.0	-31.9/4.2/-10.1/0.0
nw04	3/0/0	<b>13.4</b>	2.3	<b>14.6</b>	0.0	39.6/-8.7/-11.0/0.0
opm2-z10-s4	3/0/0	94.2	67.1	1.0	0.0	0.0/2.6/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	0.1	<b>47.3</b>	<b>6.6</b>	100.0/0.0/-23.7/-74.2
p200x1188c	3/0/0	<b>4.4</b>	0.1	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	0/3/0	63.7	0.1	5.0	0.0	5.9/0.0/0.0/0.0
peg-solitaire-a3	0/0/1	0.0	973.1	1111.0	26.0	-/-/-/-
pg	3/0/0	<b>4.5</b>	0.1	52.0	<b>15.6</b>	71.0/0.0/-0.6/18.7
pg5-34	3/0/0	<b>2.6</b>	0.2	52.0	<b>11.6</b>	63.4/0.0/0.0/14.7
physiciansched3-3	2/1/0	<b>33.1</b>	<b>434.3</b>	<b>97.0</b>	<b>0.3</b>	-62.8/30.2/-63.6/57.1
physiciansched6-2	0/2/1	<b>95.6</b>	<b>44.6</b>	729.4	26.7	-29.0/-15.0/-63.5/-93.6
piperout-08	0/0/3	<b>14.3</b>	29.0	810.3	25.0	55.2/-1.7/6.9/-60.4
piperout-27	0/0/3	<b>24.8</b>	<b>58.8</b>	1335.7	20.6	33.2/-31.1/-27.9/-73.3
pk1	3/0/0	<b>148.0</b>	0.1	64.6	<b>7.5</b>	90.4/0.0/-9.1/15.7
pp08a	3/0/0	<b>26.4</b>	0.1	<b>20.4</b>	0.0	51.0/0.0/-23.5/0.0
pp08aCUTS	3/0/0	<b>9.5</b>	0.1	<b>19.6</b>	0.0	64.0/0.0/-38.8/0.0
proteindesign121hz512p9	0/3/0	<b>4.2</b>	<b>106.2</b>	389.7	51.0	-23.8/26.1/22.6/-79.2
proteindesign122trx11p8	0/1/2	1.1	1497.0	538.7	19.1	-/-/-/-
protfold	3/0/0	<b>58.0</b>	6.3	<b>36.3</b>	<b>1.2</b>	12.8/3.1/-27.0/-66.7
qap10	3/0/0	0.0	<b>10.7</b>	2.0	0.0	0.0/10.1/0.0/0.0
qiu	3/0/0	1530.9	0.1	3.3	0.0	0.0/0.0/0.0/0.0
rB10-011000	3/0/0	<b>294.1</b>	<b>0.5</b>	<b>29.2</b>	<b>0.6</b>	-18.3/-20.0/-13.4/-100.0
rB10-011001	3/0/0	<b>231.5</b>	0.4	27.0	0.0	-11.8/0.0/-2.6/0.0
rB11-010000	3/0/0	<b>352.5</b>	1.3	28.1	<b>0.6</b>	-17.9/-7.7/5.1/-50.0
rB11-110001	3/0/0	<b>149.0</b>	<b>5.0</b>	<b>34.6</b>	<b>0.6</b>	16.7/-32.0/-15.3/-100.0
rB12-111111	0/2/1	76.2	<b>26.3</b>	532.2	67.7	-6.3/13.5/-9.5/-87.3
rC10-001000	3/0/0	<b>192.0</b>	<b>0.2</b>	29.5	0.3	33.4/-50.0/-4.1/0.0
rC10-100001	3/0/0	<b>616.9</b>	2.3	<b>93.7</b>	<b>0.6</b>	-29.2/4.2/12.7/64.7
rC11-010100	3/0/0	347.0	0.3	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>196.7</b>	<b>6.3</b>	<b>63.6</b>	<b>1.3</b>	33.1/-39.7/-53.3/-38.5
rC12-111100	3/0/0	194.9	<b>0.6</b>	1.0	0.0	0.0/-33.3/0.0/0.0
radiationm18-12-05	0/3/0	<b>1988.7</b>	<b>10.6</b>	<b>526.9</b>	<b>33.2</b>	32.4/-56.6/-53.1/-17.8
radiationm40-10-02	0/0/3	1550.2	<b>122.1</b>	1464.3	11.4	0.0/-27.6/-19.8/31.7
rail01	2/1/0	<b>30.2</b>	<b>1036.2</b>	<b>82.9</b>	<b>0.0</b>	17.5/41.8/-61.3/100.0
rail02	3/0/0	6.1	<b>2053.1</b>	4.0	0.0	0.0/-12.9/0.0/0.0

(continued)

Table A.28 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
rail507	3/0/0	23.8	2.2	1.0	0.0	0.0/-4.5/0.0/0.0
ran14x18-disj-8	3/0/0	<b>22.9</b>	0.1	22.8	0.3	-27.5/0.0/0.0/0.0
rd-rplusc-21	0/0/3	101.9	<b>108.0</b>	840.7	376.6	-0.4/16.1/-5.4/4.4
reblock115	0/3/0	<b>10.1</b>	<b>4.3</b>	<b>104.2</b>	<b>22.9</b>	12.9/-11.6/-60.1/-91.7
rmatr100-p10	3/0/0	<b>17.7</b>	0.6	2.3	0.0	40.0/0.0/0.0/0.0
rmatr200-p5	3/0/0	19.5	17.8	2.0	0.0	0.0/0.6/0.0/0.0
rocl-4-11	0/0/3	<b>94.1</b>	<b>30.2</b>	1079.3	208.2	-26.6/-30.1/-26.7/-85.3
rocll-5-11	0/0/3	<b>99.2</b>	67.4	806.0	156.9	-11.8/4.1/-1.5/-43.6
roi2alpha3n4	3/0/0	<b>33.2</b>	31.1	<b>38.8</b>	<b>2.7</b>	36.0/-9.0/-13.4/-40.7
roi5alpha10n8	3/0/0	<b>57.6</b>	497.6	<b>34.3</b>	<b>1.3</b>	13.6/-7.6/-13.4/-100.0
roll3000	0/2/1	<b>196.9</b>	<b>4.8</b>	312.4	88.9	-83.0/-85.4/-84.0/-95.2
rout	0/3/0	38.9	0.1	31.7	<b>1.5</b>	-9.0/0.0/6.8/-13.3
s100	3/0/0	<b>2.3</b>	306.8	7.3	0.0	23.3/-8.3/-9.6/0.0
s250r10	3/0/0	0.1	69.7	<b>2.3</b>	0.0	0.0/-8.8/-13.0/0.0
satellites2-40	1/2/0	<b>562.8</b>	<b>1151.4</b>	<b>91.4</b>	<b>22.8</b>	-41.3/-33.4/-58.1/-80.3
satellites2-60-fs	2/0/0	323.7	919.0	92.7	29.6	-/-/-/-
savsched1	3/0/0	<b>8.2</b>	<b>127.2</b>	12.0	0.0	-24.4/-10.8/-5.8/0.0
sct2	3/0/0	<b>26.7</b>	<b>0.3</b>	<b>36.7</b>	<b>2.9</b>	-50.6/-33.3/-39.2/-100.0
set1ch	3/0/0	61.7	0.1	31.0	1.0	-9.2/0.0/0.0/0.0
seymour	3/0/0	12.3	<b>0.8</b>	1.0	0.0	0.0/11.1/0.0/0.0
seymour1	3/0/0	1.1	4.8	<b>9.0</b>	0.0	-9.1/9.4/-11.1/0.0
sing326	3/0/0	38.6	<b>24.7</b>	<b>53.3</b>	<b>9.0</b>	1.3/-13.0/-26.3/-60.0
sing44	3/0/0	12.1	19.1	<b>42.0</b>	<b>5.6</b>	-5.0/-7.9/-12.6/-41.1
snp-02-004-104	0/3/0	2.5	44.0	33.0	1.6	0.0/-1.8/0.9/0.0
sorrell3	3/0/0	73.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	<b>3.7</b>	0.1	31.7	<b>1.6</b>	-21.6/0.0/-1.3/-18.8
sp97ar	3/0/0	24.4	46.1	2.2	0.0	-6.1/2.9/0.0/0.0
sp98ar	3/0/0	29.0	<b>35.3</b>	1.0	0.0	0.0/13.9/0.0/0.0
splice1k1	3/0/0	98.2	126.4	<b>15.0</b>	0.0	0.4/-3.2/-13.3/0.0
square41	0/3/0	<b>23.8</b>	<b>1872.8</b>	<b>19.3</b>	0.0	-71.8/-57.3/-48.2/0.0
square47	0/2/0	14.8	2942.0	23.1	0.0	-/-/-/-
supportcase10	3/0/0	<b>165.7</b>	1192.0	<b>14.9</b>	0.0	14.9/-1.9/-12.8/0.0
supportcase12	0/3/0	<b>2.0</b>	<b>25.9</b>	25.3	<b>0.0</b>	60.0/15.1/-2.0/100.0
supportcase18	3/0/0	77.1	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>3690.2</b>	0.1	90.3	60.3	-98.8/0.0/-0.7/5.3
supportcase33	0/3/0	<b>60.8</b>	<b>11.9</b>	<b>281.1</b>	<b>57.8</b>	24.8/60.2/-18.0/28.8
supportcase40	3/0/0	<b>21.0</b>	<b>5.2</b>	<b>19.0</b>	0.0	-16.2/14.8/-12.6/0.0
supportcase42	0/3/0	15.7	<b>10.4</b>	<b>16.9</b>	<b>0.3</b>	0.0/-17.3/-36.7/-100.0
supportcase6	3/0/0	<b>0.5</b>	<b>59.8</b>	<b>11.8</b>	0.0	81.5/37.4/18.6/0.0
supportcase7	3/0/0	<b>33.7</b>	68.6	24.8	0.0	27.4/-4.1/-1.6/0.0
swath	0/1/2	<b>80.7</b>	<b>74.1</b>	660.9	259.0	60.1/-73.0/-72.0/-78.3
swath1	3/0/0	<b>18.2</b>	<b>2.3</b>	62.4	15.0	73.8/41.0/-0.6/8.0
swath3	3/0/0	<b>24.9</b>	<b>2.0</b>	<b>53.2</b>	<b>8.2</b>	-54.6/45.9/10.4/46.8
t1717	3/0/0	<b>133.7</b>	<b>191.6</b>	<b>44.4</b>	<b>0.0</b>	34.4/27.1/23.4/100.0
tbfp-network	3/0/0	<b>146.4</b>	<b>162.6</b>	<b>17.2</b>	0.0	-60.4/-56.0/-59.3/0.0
thor50dday	3/0/0	257.8	5.5	24.5	1.7	0.0/-3.6/0.0/0.0
timtab1	0/3/0	<b>60.1</b>	<b>0.2</b>	<b>139.9</b>	<b>49.3</b>	20.2/-50.0/-24.9/-32.9
timtab2	0/2/1	84.9	<b>2.2</b>	487.2	216.8	1.2/12.0/18.0/2.5
tr12-30	3/0/0	67.0	0.1	31.3	<b>1.3</b>	9.1/0.0/-1.0/-23.1
traininstance2	0/2/1	<b>149.8</b>	<b>15.6</b>	684.6	92.5	56.6/37.3/44.4/-22.4
traininstance6	0/0/3	<b>272.1</b>	<b>13.3</b>	905.0	99.8	55.3/-36.8/-30.1/-51.2
trento1	3/0/0	<b>11.0</b>	32.2	3.3	0.0	12.7/-3.4/0.0/0.0
triptim1	0/3/0	0.1	<b>108.6</b>	<b>4.8</b>	0.0	0.0/16.4/12.7/0.0
uccase12	3/0/0	0.0	15.7	21.5	0.0	0.0/9.8/-4.7/0.0
uccase9	3/0/0	<b>1585.0</b>	<b>25.9</b>	108.6	44.5	-38.3/42.3/50.2/47.0
uct-subprob	3/0/0	<b>12.4</b>	0.1	<b>9.3</b>	0.0	10.8/0.0/-21.5/0.0
unitcal-7	0/0/3	46.4	<b>115.2</b>	845.3	165.3	0.0/25.0/13.5/8.2
var-smallemerly-m6j6	3/0/0	<b>22.2</b>	25.1	72.0	<b>12.6</b>	61.7/-3.2/-6.9/-26.2
vpms	3/0/0	<b>28.0</b>	0.1	31.0	1.0	20.0/0.0/0.0/0.0
wachplan	0/3/0	0.0	1.4	<b>33.6</b>	<b>0.3</b>	0.0/-7.1/-27.7/-100.0

(continued)

Table A.28 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
Geom. means		(259 instances)	(213 instances)			
FP		42.8	6.2	15.7	1.2	
FP+(3,sv,g)		<b>39.8</b>	<b>6.7</b>	<b>18.1</b>	<b>1.5</b>	

Table A.29.: Performance of FP+(3,sv,g,c, $\Delta$ ) with CPLEX

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	1/1/1	<b>6.1</b>	<b>4.2</b>	130.9	8.5	12.9/-59.5/-63.6/-100.0
30n20b8	0/3/0	<b>406.6</b>	<b>12.7</b>	769.6	127.0	-45.4/36.2/33.1/52.4
50v-10	0/3/0	<b>138.0</b>	<b>0.1</b>	<b>19.3</b>	<b>0.0</b>	-17.0/50.0/33.9/100.0
CMS750-4	3/0/0	<b>88.3</b>	<b>5.7</b>	<b>121.7</b>	<b>24.5</b>	-32.2/-40.4/-46.4/-44.1
a1c1s1	3/0/0	<b>23.6</b>	0.2	32.0	<b>1.9</b>	33.9/0.0/-0.9/-15.8
academictimetablesmall	0/0/3	inf	<b>1333.7</b>	1174.1	0.7	0.0/38.8/-11.1/-100.0
aflow30a	3/0/0	<b>187.1</b>	0.1	<b>64.9</b>	<b>18.1</b>	29.4/0.0/-40.1/-72.9
aflow40b	3/0/0	<b>199.9</b>	<b>0.3</b>	<b>54.1</b>	<b>10.3</b>	20.4/-33.3/-18.1/-36.9
air04	3/0/0	<b>2.7</b>	<b>15.0</b>	<b>7.1</b>	0.0	-66.7/30.6/26.0/0.0
air05	3/0/0	<b>3.9</b>	4.0	<b>16.1</b>	0.0	-61.5/-7.5/-73.3/0.0
app1-1	3/0/0	<b>66.7</b>	<b>0.3</b>	<b>57.6</b>	<b>20.3</b>	-100.0/-33.3/-38.0/-78.8
app1-2	3/0/0	45.5	<b>7.5</b>	39.8	<b>7.0</b>	-5.3/13.8/1.7/12.5
arki001	0/1/2	2.1	<b>10.9</b>	827.2	240.0	0.0/-40.4/-54.8/-66.3
assign1-5-8	3/0/0	<b>5.9</b>	0.1	<b>5.6</b>	0.0	-72.9/0.0/72.3/0.0
atlanta-ip	0/3/0	<b>25.6</b>	<b>52.0</b>	<b>66.6</b>	<b>7.7</b>	21.2/-11.7/-29.4/-90.9
b1c1s1	3/0/0	<b>113.0</b>	0.2	35.0	<b>4.6</b>	34.2/0.0/-3.7/-21.7
bab2	0/0/3	59.5	1666.9	1998.0	363.0	-/-/-/-
bab6	0/0/3	<b>43.0</b>	<b>495.7</b>	936.9	77.9	-30.5/-29.9/-56.3/-10.9
beasleyC3	3/0/0	11.3	0.1	35.7	<b>5.6</b>	8.1/0.0/-2.0/-14.3
binkar10-1	3/0/0	<b>1.5</b>	0.1	5.5	0.0	61.5/0.0/8.3/0.0
blp-ar98	3/0/0	60.1	1.3	10.3	0.0	-6.7/-7.7/3.7/0.0
blp-ic98	3/0/0	<b>16.8</b>	<b>0.7</b>	<b>4.3</b>	0.0	22.2/22.2/34.8/0.0
bnatt400	0/0/0	-	-	-	-	-/-/-/-
bppc4-08	3/0/0	<b>37.0</b>	<b>0.1</b>	<b>6.0</b>	<b>0.0</b>	27.9/75.0/90.3/100.0
brazil3	0/3/0	<b>393.0</b>	<b>50.1</b>	<b>41.6</b>	0.0	31.3/-44.5/-40.1/0.0
buildingenergy	0/3/0	0.9	1574.1	3.6	0.0	-/-/-/-
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	inf	<b>1.9</b>	<b>36.1</b>	<b>4.0</b>	0.0/-10.5/-13.3/-67.5
chromaticindex1024-7	3/0/0	0.0	<b>27.3</b>	<b>4.8</b>	0.0	0.0/-74.4/-58.3/0.0
chromaticindex512-7	3/0/0	0.0	<b>9.7</b>	<b>3.8</b>	0.0	0.0/-69.1/-47.4/0.0
cmflsp50-24-8-8	3/0/0	<b>14.9</b>	<b>23.8</b>	114.3	29.7	30.0/90.2/90.8/91.5
co-100	3/0/0	<b>397.0</b>	<b>2.7</b>	<b>13.6</b>	0.0	-12.6/30.8/31.7/0.0
cod105	3/0/0	100.0	2.0	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	4028.8	<b>21.6</b>	<b>60.3</b>	<b>1.3</b>	-0.7/-15.7/-57.0/-100.0
comp21-2idx	0/3/0	<b>517.3</b>	<b>25.3</b>	<b>63.3</b>	<b>1.3</b>	-32.8/-32.0/-66.5/-100.0
cost266-UUE	3/0/0	<b>49.2</b>	0.4	<b>19.1</b>	0.3	-27.8/0.0/29.5/0.0
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/1/2	<b>38.6</b>	<b>6.7</b>	1204.1	322.0	58.4/-37.3/-35.7/-48.0
csched008	1/2/0	8.9	1.0	239.6	<b>66.9</b>	-5.6/9.1/-6.6/-19.4
cvs16r128-89	3/0/0	97.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	<b>67.9</b>	<b>2.0</b>	0.0	0.0/-30.6/86.2/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>67.5</b>	<b>2.0</b>	<b>0.0</b>	-33.3/51.4/93.2/100.0
dano3mip	3/0/0	15.4	<b>105.3</b>	<b>5.0</b>	<b>0.0</b>	4.3/91.8/92.9/100.0
danooint	2/1/0	<b>21.6</b>	<b>0.7</b>	<b>119.3</b>	<b>31.9</b>	22.3/30.0/-27.4/-13.5
disctom	3/0/0	0.0	<b>3.9</b>	<b>4.0</b>	0.0	0.0/-28.2/-25.0/0.0
drayage-100-23	3/0/0	29.0	<b>0.2</b>	<b>7.1</b>	0.0	6.5/33.3/62.4/0.0
drayage-25-23	3/0/0	28.3	0.2	<b>9.0</b>	0.0	4.4/0.0/-22.2/0.0
ds	0/0/0	-	-	-	-	-/-/-/-
dws008-01	0/0/3	45.0	41.6	849.6	221.7	-/-/-/-
eil33-2	0/2/1	<b>80.1</b>	<b>28.7</b>	434.8	104.9	-34.0/-95.1/-93.2/-99.6

(continued)

Table A.29 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
eilA101-2	0/2/1	<b>163.5</b>	<b>2572.4</b>	568.7	8.0	58.4/22.5/18.7/-17.5
enlight-hard	0/0/3	0.0	<b>1.0</b>	849.9	256.0	0.0/-20.0/-5.4/37.5
exp-1-500-5-5	3/0/0	<b>151.3</b>	0.1	<b>23.4</b>	0.0	-49.6/0.0/13.0/0.0
fast0507	3/0/0	23.8	1.5	1.0	0.0	0.0/-6.7/0.0/0.0
fastxgemm-n2r6s0t2	3/0/0	<b>1074.2</b>	<b>0.2</b>	<b>44.0</b>	<b>3.3</b>	-51.4/-50.0/-62.3/-100.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>14.9</b>	<b>0.8</b>	<b>8.3</b>	<b>0.0</b>	-14.1/78.9/84.4/100.0
fiber	3/0/0	173.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
fixnet6	3/0/0	<b>34.0</b>	0.1	31.0	1.0	-18.5/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	15.0	0.1	1.3	0.0	0.0/0.0/0.0/0.0
germanrr	0/3/0	<b>3.3</b>	<b>11.5</b>	<b>87.1</b>	<b>21.3</b>	-24.2/-60.0/-69.3/-100.0
gesa2	0/3/0	2.3	0.1	20.4	0.0	-8.7/0.0/0.0/0.0
gesa2-o	0/3/0	21.0	0.1	34.6	<b>1.6</b>	0.0/0.0/-1.7/27.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.2	1.0	0.0	0.0/0.0/0.0/0.0
glass4	2/1/0	<b>584.2</b>	0.1	<b>114.4</b>	<b>44.4</b>	-16.0/0.0/19.0/36.7
gmu-35-40	2/1/0	<b>2.0</b>	0.2	72.5	<b>11.0</b>	56.5/0.0/-4.6/-25.5
gmu-35-50	2/1/0	<b>2.0</b>	<b>0.5</b>	<b>131.7</b>	<b>24.5</b>	-45.0/-80.0/-89.9/-100.0
graph20-20-1rand	3/0/0	<b>11.1</b>	<b>21.7</b>	<b>20.3</b>	0.0	60.4/-65.9/11.7/0.0
graphdraw-domain	0/3/0	<b>68.7</b>	0.1	<b>59.6</b>	<b>11.9</b>	-33.8/0.0/16.3/17.9
h80x6320d	3/0/0	<b>34.0</b>	1.4	33.3	2.2	-10.9/-7.1/0.0/0.0
harp2	3/0/0	11.2	0.1	13.6	0.0	0.9/0.0/-4.4/0.0
highschool1-aigio	0/3/0	inf	<b>844.9</b>	<b>51.9</b>	<b>0.3</b>	0.0/-65.1/-43.2/50.0
hypothyroid-k1	3/0/0	0.0	32.1	1.0	0.0	0.0/-3.7/0.0/0.0
ic97p	0/0/3	15.2	<b>2.4</b>	779.6	251.5	1.9/27.3/25.5/-11.1
ic97t	0/1/0	11.1	0.7	578.0	257.0	-/-/-/-
icir97p	0/0/3	20.6	14.5	999.4	221.0	2.4/-6.9/-3.0/-39.8
icir97t	0/2/1	<b>16.2</b>	<b>10.9</b>	720.8	458.0	-11.7/-84.4/-77.8/-78.3
irish-electricity	0/0/3	43.0	<b>974.7</b>	1208.1	4.6	4.9/27.2/2.7/82.8
irp	3/0/0	<b>2.0</b>	<b>1.5</b>	<b>20.1</b>	0.0	-50.0/-40.0/-30.8/0.0
istanbul-no-cutoff	3/0/0	<b>39.7</b>	<b>5.1</b>	<b>14.3</b>	0.0	-42.1/-35.3/-37.1/0.0
k1mushroom	3/0/0	18.2	25.9	1.0	0.0	0.0/0.4/0.0/0.0
lectsched-5-obj	0/0/3	2755.0	<b>124.5</b>	1439.2	0.0	-3.1/-31.0/-29.3/100.0
leo1	3/0/0	50.6	0.2	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	48.3	0.2	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>403.4</b>	<b>0.1</b>	<b>16.5</b>	<b>0.0</b>	40.2/80.0/82.3/100.0
lotsize	3/0/0	<b>233.2</b>	0.3	43.3	8.3	-73.1/0.0/7.1/8.8
mad	3/0/0	<b>6498.4</b>	0.1	13.9	0.0	30.8/0.0/0.7/0.0
manna81	0/3/0	1.1	0.1	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>63.5</b>	<b>26.2</b>	<b>7.7</b>	<b>0.0</b>	-52.8/58.7/80.8/100.0
map16715-04	3/0/0	<b>70.4</b>	<b>31.4</b>	<b>8.3</b>	<b>0.0</b>	21.1/70.7/82.1/100.0
markshare1	3/0/0	<b>70959.8</b>	0.1	<b>60.3</b>	<b>8.7</b>	-31.4/0.0/14.2/46.6
markshare2	3/0/0	<b>29620.2</b>	0.1	<b>56.4</b>	<b>5.9</b>	66.8/0.0/19.8/62.2
markshare-4-0	3/0/0	<b>32549.4</b>	0.1	65.0	<b>12.6</b>	-44.5/0.0/0.0/20.8
mas74	0/3/0	<b>41.0</b>	0.1	<b>8.6</b>	<b>0.0</b>	23.5/0.0/90.4/100.0
mas76	0/3/0	<b>12.2</b>	0.1	<b>5.3</b>	<b>0.0</b>	36.8/0.0/94.2/100.0
mc11	3/0/0	116.3	<b>0.5</b>	43.3	13.3	-8.6/-20.0/-2.3/-7.5
mcsched	3/0/0	<b>24.7</b>	0.2	3.6	0.0	-50.2/0.0/0.0/0.0
mik-250-20-75-4	0/3/0	<b>28.4</b>	0.1	<b>6.9</b>	<b>0.0</b>	53.5/0.0/82.0/100.0
milo-v12-6-r2-40-1	3/0/0	<b>128.1</b>	1.5	42.6	12.6	14.5/-6.7/-1.4/-5.6
misc07	3/0/0	29.5	0.1	<b>27.9</b>	<b>0.0</b>	8.1/0.0/-18.3/100.0
mkc	0/3/0	70.8	0.1	2.0	0.0	0.0/0.0/0.0/0.0
mod011	0/0/0	-	-	-	-	-/-/-/-
modglob	3/0/0	<b>50.8</b>	0.1	<b>6.0</b>	<b>0.0</b>	-99.6/0.0/80.8/100.0
momentum1	0/0/3	<b>389.1</b>	<b>123.9</b>	787.5	475.0	-29.8/11.4/17.5/34.5
msc98-ip	0/3/0	<b>20.3</b>	<b>1.8</b>	<b>11.3</b>	0.0	-34.0/28.0/25.2/0.0
mushroom-best	0/3/0	<b>3.51e06</b>	<b>89.8</b>	<b>101.7</b>	<b>30.7</b>	63.7/-79.4/-53.8/-96.7
mzzv11	0/3/0	<b>22.0</b>	<b>3.4</b>	<b>30.6</b>	<b>1.7</b>	-30.0/-14.7/-30.7/-100.0
mzzv42z	0/3/0	<b>18.5</b>	<b>1.2</b>	<b>6.7</b>	<b>0.0</b>	19.2/61.3/72.3/100.0
n2seq36q	3/0/0	<b>4.4</b>	<b>0.5</b>	<b>3.0</b>	0.0	47.0/-20.0/-33.3/0.0

(continued)

Table A.29 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
n3div36	3/0/0	43.5	0.3	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	35.5	0.2	20.4	0.0	-7.0/0.0/0.0/0.0
neos-1122047	3/0/0	0.6	0.3	1.0	0.0	0.0/0.0/0.0/0.0
neos-1171448	3/0/0	<b>3.9</b>	<b>1.5</b>	<b>3.6</b>	0.0	47.3/48.3/72.7/0.0
neos-1171737	3/0/0	<b>11.8</b>	<b>0.9</b>	<b>4.3</b>	0.0	-67.8/47.1/82.5/0.0
neos-1354092	0/3/0	<b>8.5</b>	<b>64.6</b>	<b>23.0</b>	0.0	47.9/36.4/32.2/0.0
neos-1445765	3/0/0	23.2	1.6	10.3	0.0	6.1/5.9/8.8/0.0
neos-1456979	0/3/0	<b>124.2</b>	<b>17.5</b>	412.2	86.0	25.3/49.3/26.2/-0.1
neos-1582420	0/1/2	74.6	<b>4.3</b>	458.1	73.2	-0.3/-74.4/-75.6/-74.0
neos-2657525-crna	0/3/0	1009.5	<b>0.1</b>	26.7	1.8	0.1/83.3/75.7/74.6
neos-2746589-doon	0/0/3	29.8	185.2	690.3	269.6	-/-/-/-
neos-2978193-inde	3/0/0	<b>12.6</b>	0.1	<b>3.9</b>	0.0	55.2/0.0/-33.3/0.0
neos-2987310-joes	3/0/0	<b>0.4</b>	11.5	51.1	<b>7.6</b>	33.3/0.9/0.4/33.9
neos-3004026-krka	0/0/2	0.0	103.9	1633.2	1.4	-/-/-/-
neos-3024952-loue	0/0/3	<b>888.1</b>	<b>67.8</b>	1549.8	1.1	-10.8/-38.1/-19.0/95.7
neos-3046615-murg	0/3/0	<b>33.1</b>	0.1	<b>15.0</b>	<b>0.0</b>	99.8/0.0/85.6/100.0
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	131.1	1120.1	1212.1	298.2	-/-/-/-
neos-3381206-awhea	0/0/3	<b>2.5</b>	<b>29.3</b>	1698.2	34.1	49.0/-70.0/-49.8/-100.0
neos-3402294-bobin	3/0/0	<b>269.0</b>	<b>23.4</b>	<b>22.6</b>	0.0	61.7/-59.0/-33.2/0.0
neos-3555904-turama	0/1/2	8.4	<b>1259.4</b>	681.9	76.1	0.0/33.0/-13.0/17.7
neos-3627168-kasai	3/0/0	2.3	0.1	<b>20.4</b>	<b>0.0</b>	-4.3/0.0/25.0/100.0
neos-3656078-kumeu	0/0/0	-	-	-	-	-/-/-/-
neos-3754480-nidda	3/0/0	<b>32.1</b>	0.1	<b>18.6</b>	<b>0.0</b>	-52.3/0.0/72.6/100.0
neos-4300652-rahue	0/1/2	<b>183.1</b>	<b>595.6</b>	505.7	1.6	11.3/31.2/33.6/-81.2
neos-4338804-snowy	0/3/0	<b>88739.5</b>	<b>0.9</b>	<b>260.8</b>	<b>62.7</b>	31.2/-22.2/-25.4/-26.6
neos-4387871-tavua	0/1/2	<b>927.5</b>	<b>10.5</b>	672.0	373.5	-11.8/-11.4/-12.5/-22.6
neos-4413714-turia	3/0/0	<b>168.2</b>	<b>60.0</b>	<b>9.0</b>	<b>0.0</b>	99.3/88.3/89.9/100.0
neos-4532248-waihi	0/0/3	949.4	858.5	1323.2	151.2	0.0/-3.9/-34.1/-73.2
neos-4647030-tutaki	3/0/0	<b>52.4</b>	29.2	<b>23.6</b>	<b>0.3</b>	-40.1/-7.5/-13.6/-100.0
neos-4722843-widden	0/3/0	39.0	16.2	48.2	<b>6.5</b>	-0.3/3.0/0.8/30.1
neos-4738912-atrato	0/3/0	<b>8.7</b>	0.3	18.5	<b>0.3</b>	28.1/0.0/-3.8/-100.0
neos-4763324-toguru	3/0/0	<b>34.4</b>	<b>58.6</b>	<b>9.3</b>	0.0	-10.8/-21.5/56.3/0.0
neos-4954672-berkel	3/0/0	<b>96.9</b>	0.1	<b>13.8</b>	<b>0.0</b>	-52.7/0.0/57.3/100.0
neos-5049753-cuanza	0/0/3	<b>49.3</b>	<b>1501.7</b>	1226.8	235.3	27.8/-44.3/-43.0/-44.4
neos-5052403-cygnnet	3/0/0	<b>0.2</b>	71.7	<b>2.3</b>	0.0	33.3/-0.1/-13.0/0.0
neos-5093327-huahum	3/0/0	<b>31.1</b>	<b>4.2</b>	<b>31.3</b>	<b>2.7</b>	84.9/73.6/68.7/91.6
neos-5104907-jarama	0/0/0	-	-	-	-	-/-/-/-
neos-5107597-kakapo	1/2/0	<b>13140.7</b>	<b>24.7</b>	<b>543.1</b>	<b>484.4</b>	63.2/-21.5/-24.6/-23.7
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	4522.9	<b>3.4</b>	<b>17.6</b>	0.0	-4.0/32.0/31.2/0.0
neos-5195221-niemur	3/0/0	<b>1362.4</b>	<b>31.8</b>	<b>25.3</b>	0.0	-30.0/-77.7/-54.9/0.0
neos-631710	3/0/0	173.9	1.6	1.0	0.0	0.0/0.0/0.0/0.0
neos-662469	0/3/0	1574.2	4.2	2.9	0.0	-2.9/-2.4/0.0/0.0
neos-787933	0/3/0	0.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	0.0	<b>0.9</b>	<b>2.3</b>	0.0	0.0/18.2/23.3/0.0
neos-848589	3/0/0	<b>2.78e05</b>	63.8	<b>77.0</b>	<b>22.6</b>	-81.8/2.9/-14.9/-19.0
neos-860300	3/0/0	<b>55.0</b>	<b>0.5</b>	<b>13.1</b>	0.0	-34.4/-60.0/-69.5/0.0
neos-873061	3/0/0	52.1	53.3	31.3	1.3	6.0/-3.2/0.0/0.0
neos-911970	3/0/0	<b>197.0</b>	0.1	<b>18.6</b>	<b>0.0</b>	-12.4/0.0/64.2/100.0
neos-933966	3/0/0	<b>2.9</b>	<b>8.5</b>	<b>6.2</b>	0.0	97.6/-74.1/36.7/0.0
neos-950242	2/1/0	<b>62.3</b>	<b>82.0</b>	<b>52.9</b>	<b>2.4</b>	21.9/-74.6/-57.3/-83.3
neos-957323	3/0/0	11.4	<b>2.7</b>	1.3	0.0	0.0/-29.6/0.0/0.0
neos-960392	3/0/0	<b>3.8</b>	<b>4.8</b>	<b>5.5</b>	0.0	-78.9/-16.7/21.4/0.0
neos10	0/3/0	117.8	0.1	2.9	0.0	7.3/0.0/0.0/0.0
neos16	0/0/0	-	-	-	-	-/-/-/-
neos17	3/0/0	253.5	0.1	34.9	<b>2.7</b>	0.0/0.0/-9.2/-40.7
neos20	0/0/3	69.8	5.7	853.8	35.3	-/-/-/-
neos5	3/0/0	<b>38.8</b>	0.1	<b>2.7</b>	0.0	-32.7/0.0/18.2/0.0
neos7	0/3/0	<b>18.8</b>	0.1	<b>7.0</b>	<b>0.0</b>	10.5/0.0/84.5/100.0
neos8	0/3/0	20.7	0.1	2.6	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.29 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
net12	3/0/0	<b>38.3</b>	<b>7.2</b>	<b>48.0</b>	<b>1.3</b>	-20.4/-16.7/-26.0/-76.9
netdiversion	3/0/0	82.9	<b>210.2</b>	<b>15.5</b>	0.0	8.4/-76.3/-37.4/0.0
nexp-150-20-8-5	3/0/0	142.4	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nh97p	0/0/3	<b>11.1</b>	<b>6.1</b>	827.8	135.7	11.2/24.7/17.5/36.6
nh97t	0/0/3	<b>9.6</b>	<b>11.7</b>	1181.6	261.2	14.3/-27.4/-23.4/-15.0
noswot	0/3/0	<b>7.6</b>	0.1	<b>11.8</b>	<b>0.8</b>	-11.8/0.0/65.1/20.0
ns1116954	0/2/1	0.0	<b>578.4</b>	581.5	14.7	0.0/-59.7/-77.6/-64.6
ns1208400	2/1/0	0.0	89.0	<b>212.3</b>	<b>2.0</b>	0.0/8.2/-10.8/-100.0
ns1644855	3/0/0	<b>22.2</b>	<b>416.5</b>	<b>4.6</b>	<b>0.0</b>	-95.0/71.1/89.8/100.0
ns1760995	3/0/0	<b>22.3</b>	<b>73.4</b>	<b>20.7</b>	<b>0.0</b>	-16.1/76.1/74.1/100.0
ns1830653	1/0/2	<b>176.0</b>	<b>5.4</b>	332.9	28.7	27.4/19.4/18.5/61.4
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-idx	3/0/0	47.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	2.6	<b>0.1</b>	<b>3.0</b>	0.0	0.0/66.7/80.9/0.0
nursesched-medium-hint03	0/3/0	<b>616.0</b>	<b>90.4</b>	<b>43.6</b>	<b>0.3</b>	16.4/-84.5/-68.3/-100.0
nursesched-sprint02	0/3/0	86.7	<b>3.1</b>	<b>21.3</b>	0.0	7.8/-22.6/-45.5/0.0
nw04	3/0/0	<b>13.4</b>	<b>1.3</b>	<b>7.0</b>	0.0	39.6/38.1/46.2/0.0
opm2-z10-s4	3/0/0	94.2	64.7	1.0	0.0	0.0/6.1/0.0/0.0
opt1217	3/0/0	<b>0.0</b>	0.1	<b>4.9</b>	<b>0.0</b>	100.0/0.0/86.4/100.0
p200x1188c	3/0/0	3.9	0.1	31.0	1.0	0.0/0.0/0.0/0.0
p2756	0/3/0	67.7	0.1	<b>8.0</b>	0.0	0.0/0.0/-37.5/0.0
peg-solitaire-a3	0/0/1	0.0	1721.5	889.0	0.0	-/-/-/-
pg	3/0/0	<b>4.7</b>	0.1	<b>16.6</b>	<b>0.0</b>	69.7/0.0/67.9/100.0
pg5-34	3/0/0	7.6	<b>0.1</b>	<b>7.4</b>	<b>0.0</b>	-6.6/50.0/85.8/100.0
physiciansched3-3	0/1/2	<b>730.7</b>	609.2	554.8	17.1	-98.3/2.1/-93.6/-95.9
physiciansched6-2	0/2/1	<b>95.6</b>	36.1	561.9	11.1	-29.0/4.7/-52.6/-84.7
piperout-08	0/0/3	<b>23.5</b>	<b>40.4</b>	1150.0	12.4	26.3/-29.5/-24.3/-20.2
piperout-27	0/0/3	<b>52.4</b>	<b>76.2</b>	1613.1	4.3	-29.2/-46.9/-40.3/21.8
pk1	3/0/0	<b>63.6</b>	0.1	<b>24.0</b>	<b>0.0</b>	95.9/0.0/59.1/100.0
pp08a	3/0/0	<b>41.5</b>	0.1	16.7	0.0	23.0/0.0/-6.6/0.0
pp08aCUTS	3/0/0	<b>14.4</b>	0.1	<b>10.5</b>	0.0	45.5/0.0/12.5/0.0
proteindesign121hz512p9	0/3/0	<b>2.6</b>	<b>25.0</b>	127.2	18.3	18.8/82.6/74.7/-42.1
proteindesign122trx11p8	0/3/0	3.0	441.6	236.0	20.0	-/-/-/-
protfold	3/0/0	61.4	<b>3.0</b>	<b>20.1</b>	<b>0.0</b>	7.7/53.8/24.2/100.0
qap10	3/0/0	0.0	<b>10.2</b>	2.0	0.0	0.0/14.3/0.0/0.0
qiu	3/0/0	1510.8	0.1	3.3	0.0	1.3/0.0/0.0/0.0
rB10-011000	3/0/0	<b>319.8</b>	0.4	23.0	<b>0.3</b>	-24.9/0.0/9.1/-100.0
rB10-011001	3/0/0	<b>229.0</b>	0.4	<b>22.7</b>	0.0	-10.9/0.0/13.7/0.0
rB11-010000	3/0/0	<b>384.4</b>	<b>1.4</b>	27.0	0.3	-24.7/-14.3/8.8/0.0
rB11-110001	3/0/0	186.1	<b>4.5</b>	29.3	0.0	-3.9/-24.4/0.0/0.0
rB12-111111	0/2/1	73.6	<b>22.7</b>	496.6	49.7	-3.0/25.3/-3.0/-82.7
rC10-001000	3/0/0	275.0	<b>0.2</b>	29.5	0.3	4.6/-50.0/-4.1/0.0
rC10-100001	3/0/0	<b>385.6</b>	<b>3.4</b>	<b>122.8</b>	<b>0.6</b>	11.7/-29.4/-12.6/64.7
rC11-010100	3/0/0	347.0	0.3	1.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	3/0/0	480.5	0.2	1.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	2/1/0	<b>442.6</b>	<b>6.5</b>	<b>57.0</b>	<b>1.1</b>	-33.6/-41.5/-47.9/-27.3
rC12-111100	3/0/0	194.9	<b>0.5</b>	1.0	0.0	0.0/-20.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>384.9</b>	<b>5.7</b>	<b>294.9</b>	27.7	86.9/-19.3/-16.2/-1.4
radiationm40-10-02	0/0/3	1550.2	<b>121.0</b>	1524.1	10.7	0.0/-26.9/-23.0/35.9
rail01	3/0/0	<b>28.9</b>	1866.6	<b>12.0</b>	<b>0.0</b>	21.0/-4.7/62.6/100.0
rail02	3/0/0	<b>4.3</b>	<b>2993.8</b>	<b>6.6</b>	0.0	29.5/-40.3/-39.4/0.0
rail507	3/0/0	23.8	2.2	1.0	0.0	0.0/-4.5/0.0/0.0
ran14x18-disj-8	3/0/0	<b>37.5</b>	0.1	23.5	<b>0.8</b>	-55.7/0.0/-3.0/-62.5
rd-rplusc-21	0/0/3	101.9	<b>114.2</b>	915.2	425.9	-0.4/11.3/-13.1/-7.5
reblock115	0/3/0	12.5	4.0	<b>101.4</b>	<b>19.1</b>	-7.2/-5.0/-59.0/-90.1
rmatr100-p10	3/0/0	<b>3.2</b>	<b>0.8</b>	<b>5.3</b>	0.0	89.2/-25.0/-56.6/0.0
rmatr200-p5	3/0/0	<b>16.5</b>	<b>25.0</b>	<b>6.6</b>	0.0	15.4/-28.4/-69.7/0.0
rocl-4-11	0/0/3	63.0	<b>31.6</b>	1130.9	214.4	8.8/-33.2/-30.0/-85.7
rocll-5-11	0/0/3	80.2	73.4	879.9	128.5	8.3/-4.2/-9.8/-31.1
roi2alpha3n4	3/0/0	<b>59.2</b>	<b>6.3</b>	<b>7.0</b>	<b>0.0</b>	-12.3/77.7/79.2/100.0
roi5alpha10n8	3/0/0	<b>56.6</b>	<b>92.3</b>	<b>8.0</b>	0.0	15.1/79.9/73.1/0.0

(continued)

Table A.29 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
roll3000	0/2/1	<b>250.1</b>	<b>6.3</b>	430.0	137.6	-86.6/-88.9/-88.4/-96.9
rout	0/3/0	37.2	0.1	<b>29.5</b>	<b>1.0</b>	-4.8/0.0/13.2/23.1
s100	3/0/0	<b>6.5</b>	253.2	7.2	0.0	-53.8/10.0/-8.3/0.0
s250r10	3/0/0	0.1	62.4	2.0	0.0	0.0/1.9/0.0/0.0
satellites2-40	0/1/2	<b>243.8</b>	<b>1631.2</b>	431.3	192.5	26.1/-53.0/-91.1/-97.7
satellites2-60-fs	0/1/0	347.4	2437.8	147.0	57.0	-/-/-/-
savsched1	3/0/0	<b>11.6</b>	122.9	<b>7.0</b>	0.0	-46.6/-7.6/38.1/0.0
sct2	3/0/0	13.7	<b>0.1</b>	<b>6.0</b>	0.0	-3.6/50.0/73.1/0.0
set1ch	3/0/0	<b>38.6</b>	0.1	31.0	1.0	31.1/0.0/0.0/0.0
seymour	3/0/0	12.3	<b>0.8</b>	1.0	0.0	0.0/11.1/0.0/0.0
seymour1	3/0/0	<b>11.1</b>	<b>2.6</b>	<b>3.3</b>	0.0	-91.0/50.9/58.8/0.0
sing326	3/0/0	<b>52.5</b>	<b>10.7</b>	<b>9.0</b>	<b>0.0</b>	-25.5/50.2/77.1/100.0
sing44	3/0/0	<b>31.1</b>	<b>9.4</b>	<b>4.6</b>	<b>0.0</b>	-63.0/46.6/87.5/100.0
snp-02-004-104	0/3/0	<b>14.2</b>	42.6	34.0	<b>2.0</b>	-82.4/1.4/-2.1/-20.0
sorrell3	3/0/0	73.7	0.7	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	2.9	0.1	31.3	1.3	0.0/0.0/0.0/0.0
sp97ar	3/0/0	24.1	47.6	2.2	0.0	-5.0/-0.2/0.0/0.0
sp98ar	3/0/0	29.0	40.0	1.0	0.0	0.0/2.4/0.0/0.0
splice1k1	3/0/0	99.0	123.4	<b>9.0</b>	0.0	-0.4/-0.9/30.8/0.0
square41	0/3/0	<b>24.5</b>	<b>3120.5</b>	<b>28.0</b>	0.0	-72.7/-74.4/-64.3/0.0
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>42.9</b>	<b>399.2</b>	<b>6.0</b>	0.0	78.0/65.8/53.8/0.0
supportcase12	0/3/0	<b>5.7</b>	<b>14.3</b>	<b>3.9</b>	<b>0.0</b>	-12.3/53.1/84.3/100.0
supportcase18	3/0/0	77.1	0.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>26.2</b>	0.1	<b>7.0</b>	<b>0.0</b>	42.7/0.0/92.2/100.0
supportcase33	0/3/0	<b>71.1</b>	<b>6.9</b>	<b>142.7</b>	<b>16.5</b>	12.1/76.9/38.1/79.7
supportcase40	3/0/0	<b>48.7</b>	<b>3.5</b>	<b>8.0</b>	0.0	-63.9/42.6/51.8/0.0
supportcase42	0/3/0	17.2	8.3	<b>6.2</b>	0.0	-8.7/3.5/42.1/0.0
supportcase6	3/0/0	<b>0.6</b>	<b>21.4</b>	<b>5.0</b>	0.0	77.8/77.6/65.5/0.0
supportcase7	3/0/0	<b>30.0</b>	<b>95.0</b>	<b>9.0</b>	0.0	35.3/-30.7/63.1/0.0
swath	0/1/2	<b>72.9</b>	<b>51.1</b>	498.1	186.8	63.9/-60.9/-62.9/-70.0
swath1	3/0/0	<b>10.9</b>	<b>2.5</b>	59.3	<b>13.6</b>	84.3/35.9/4.4/16.6
swath3	3/0/0	<b>26.1</b>	<b>2.2</b>	55.2	<b>8.7</b>	-56.7/40.5/7.1/43.5
t1717	2/1/0	<b>97.3</b>	<b>323.7</b>	<b>74.6</b>	0.3	52.2/-18.8/-22.3/0.0
tbfp-network	3/0/0	<b>36.8</b>	<b>95.2</b>	<b>12.2</b>	0.0	36.6/-24.8/-42.6/0.0
thor50dday	3/0/0	<b>300.0</b>	<b>5.9</b>	25.8	<b>1.9</b>	-14.1/-10.2/-5.0/-10.5
timtab1	0/3/0	<b>63.3</b>	<b>0.2</b>	<b>92.3</b>	36.4	15.9/-50.0/12.2/-9.1
timtab2	0/1/2	82.3	<b>4.0</b>	713.0	364.6	4.2/-37.5/-16.6/-39.0
tr12-30	3/0/0	<b>31.2</b>	0.1	<b>35.0</b>	<b>4.8</b>	57.7/0.0/-11.4/-79.2
traininstance2	0/2/1	<b>305.6</b>	<b>13.4</b>	590.7	73.2	11.5/46.2/52.0/-1.9
traininstance6	0/0/3	<b>272.1</b>	<b>15.0</b>	905.0	99.8	55.3/-44.0/-30.1/-51.2
trento1	3/0/0	<b>7.4</b>	<b>56.0</b>	<b>6.3</b>	0.0	41.3/-44.5/-47.6/0.0
triptim1	0/3/0	0.1	<b>114.1</b>	5.7	0.0	0.0/12.2/-3.5/0.0
uccase12	3/0/0	<b>1.6</b>	<b>12.7</b>	<b>16.8</b>	0.0	-100.0/27.0/18.0/0.0
uccase9	3/0/0	<b>262.8</b>	<b>11.9</b>	27.5	2.8	73.1/73.5/87.4/96.7
uct-subprob	3/0/0	<b>15.8</b>	0.1	7.7	0.0	-12.0/0.0/-5.2/0.0
unitcal-7	2/1/0	<b>28.8</b>	<b>57.9</b>	266.8	29.3	37.9/62.3/72.7/83.7
var-smallemergy-m6j6	3/0/0	<b>23.1</b>	<b>8.8</b>	<b>6.3</b>	<b>0.0</b>	60.2/63.8/90.6/100.0
vpm2	3/0/0	<b>30.0</b>	0.1	<b>23.3</b>	<b>0.6</b>	14.3/0.0/24.8/40.0
wachplan	0/3/0	0.0	<b>0.8</b>	<b>18.9</b>	0.0	0.0/38.5/22.2/0.0
Geom. means		(260 instances)		(212 instances)		
FP		43.1	6.4	15.9	1.2	
FP+(3,sv,g,c, $\Delta$ )		<b>41.3</b>	6.4	<b>12.4</b>	<b>0.8</b>	



Table A.30.: Performance of FP with SCIP

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
10teams	2/1/0	5.2	4.5	76.4	1.1
30n20b8	0/0/3	274.1	34.0	1152.8	187.9
50v-10	0/3/0	114.5	0.3	27.2	0.3
CMS750-4	3/0/0	60.2	2.6	81.2	16.4
a1c1s1	3/0/0	31.1	0.2	31.7	1.3
academictimetables	0/0/0	-	-	-	-
aflow30a	3/0/0	154.4	0.1	44.0	6.0
aflow40b	3/0/0	100.4	0.3	35.1	2.6
air04	3/0/0	0.5	4.0	8.5	0.0
air05	3/0/0	3.6	1.6	6.1	0.0
app1-1	3/0/0	15.6	0.1	33.3	2.9
app1-2	3/0/0	43.1	2.7	41.6	10.0
arki001	0/0/3	2.8	55.9	1150.9	255.2
assign1-5-8	0/3/0	1.9	0.1	24.5	0.0
atlanta-ip	3/0/0	39.5	32.2	51.4	2.3
b1c1s1	3/0/0	145.6	0.1	33.3	3.0
bab2	2/1/0	24.8	323.7	91.6	14.7
bab6	2/1/0	15.4	158.5	61.5	4.5
beasleyC3	3/0/0	12.3	0.1	35.0	4.8
binkar10-1	3/0/0	4.2	0.1	6.5	0.0
blp-ar98	3/0/0	87.7	1.6	21.1	0.7
blp-ic98	3/0/0	51.9	0.2	1.0	0.0
bnatt400	0/0/0	-	-	-	-
bppc4-08	0/3/0	38.7	0.5	59.3	8.7
brazil3	0/3/0	660.0	47.6	32.3	0.0
buildingenergy	0/1/0	1.4 <sup>(1)</sup>	3437.4	12.0	0.0
cap6000	3/0/0	0.3	0.1	1.0	0.0
cbs-cta	3/0/0	inf	2.1	31.0	1.0
chromaticindex1024-7	3/0/0	0.0	710.5	2.0	0.0
chromaticindex512-7	3/0/0	0.0	142.5	1.3	0.0
cmflsp50-24-8-8	0/0/0	-	-	-	-
co-100	3/0/0	44546.1	2.3	12.6	0.0
cod105	3/0/0	100.0	15.5	1.0	0.0
comp07-2idx	0/3/0	3445.7	14.7	21.3	0.0
comp21-2idx	0/3/0	487.7	8.5	24.8	0.0
cost266-UUE	1/0/2	76.0	0.2	11.3	0.0
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-
csched007	0/1/2	75.1	145.6	606.6	24.9
csched008	0/3/0	9.2	7.2	145.4	18.2
cvs16r128-89	3/0/0	97.9	3.3	1.0	0.0
dano3-3	3/0/0	0.0	61.0	16.2	0.0
dano3-5	3/0/0	0.1	117.5	29.6	0.8
dano3mip	3/0/0	24.2	438.1	71.7	18.6
danoint	3/0/0	24.4	4.0	128.3	46.7
disctom	3/0/0	0.0	6.2	2.0	0.0
drayage-100-23	3/0/0	144.0	1.1	33.2	0.4
drayage-25-23	3/0/0	171.1	1.5	40.9	1.3
ds	0/0/0	-	-	-	-
dws008-01	0/0/0	-	-	-	-
eil33-2	3/0/0	52.9	0.6	30.7	0.4
eilA101-2	0/3/0	169.5	1068.8	554.8	8.0
enlight-hard	0/0/0	-	-	-	-
exp-1-500-5-5	3/0/0	70.3	0.1	26.9	0.0
fast0507	3/0/0	24.2	4.6	1.0	0.0
fastxgemm-n2r6s0t2	0/0/3	2714.2	19.4	764.9	152.4
fhnw-binpack4-48	0/0/0	-	-	-	-
fiball	0/3/0	9.2	7.6	74.1	5.3
fiber	3/0/0	27192.6	0.1	1.0	0.0
fixnet6	3/0/0	27.7	0.1	31.0	1.0

(continued)

Table A.30 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
gen-ip002	0/3/0	13.9	0.1	1.0	0.0
gen-ip054	0/3/0	10.5	0.1	2.9	0.0
germanrr	0/3/0	4.3	8.1	47.2	4.9
gesa2	0/3/0	2.2	0.1	20.4	0.0
gesa2-o	0/3/0	6.8	0.1	31.7	1.3
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-
glass-sc	3/0/0	13.4	0.4	1.0	0.0
glass4	3/0/0	271.3	0.1	91.0	39.8
gmu-35-40	3/0/0	12.1	0.1	42.0	4.2
gmu-35-50	3/0/0	14.4	0.1	39.6	3.9
graph20-20-1rand	3/0/0	34.6	2.8	25.6	0.0
graphdraw-domain	0/3/0	36.5	0.1	74.6	17.3
h80x6320d	3/0/0	30.3	0.9	33.3	2.2
harp2	3/0/0	11.7	0.1	13.9	0.0
highschool1-aigio	0/0/0	-	-	-	-
hypothyroid-k1	3/0/0	96.1	24.3	72.7	14.5
ic97p	0/0/3	14.5	4.1	743.1	170.8
ic97t	0/0/2	12.1 <sup>(2)</sup>	5.4	1115.1	305.4
icir97p	0/0/3	14.0	34.3	900.3	163.3
icir97t	0/2/1	13.4	25.4	701.5	471.9
irish-electricity	3/0/0	5.7	56.6	35.5	1.8
irp	3/0/0	5.8	0.9	20.7	0.6
istanbul-no-cutoff	3/0/0	1.8	8.1	7.0	0.0
k1mushroom	3/0/0	18.2	84.3	1.0	0.0
lectsched-5-obj	0/0/1	2841.7 <sup>(1)</sup>	200.1	2196.0	17.0
leo1	3/0/0	842.0	0.2	1.0	0.0
leo2	3/0/0	7522.4	0.4	1.0	0.0
liu	1/2/0	674.7	0.6	92.7	35.9
lotsize	3/0/0	63.1	0.3	47.6	10.1
mad	3/0/0	7951.3	0.1	12.0	0.0
manna81	0/3/0	1.2	0.2	2.6	0.0
map10	3/0/0	24.8	53.5	42.8	5.9
map16715-04	3/0/0	93.3	66.5	41.3	5.5
markshare1	3/0/0	44679.3	0.1	1.0	0.0
markshare2	3/0/0	58088.2	0.1	1.0	0.0
markshare-4-0	3/0/0	6400.0	0.1	1.0	0.0
mas74	3/0/0	74.2	0.1	89.0	15.7
mas76	2/1/0	34.8	0.1	90.0	19.4
mc11	3/0/0	108.2	0.3	42.3	12.3
mcsched	3/0/0	16.7	0.4	3.6	0.0
mik-250-20-75-4	0/3/0	61.1	0.1	38.3	4.5
milo-v12-6-r2-40-1	0/0/3	94.1	24.0	889.5	0.0
misc07	3/0/0	70.4	0.1	29.1	0.3
mkc	3/0/0	25959.1	0.2	12.0	0.0
mod011	3/0/0	10.3	0.2	20.2	0.0
modglob	3/0/0	0.3	0.1	31.3	1.3
momentum1	0/2/1	232.8	12.1	312.2	198.5
msc98-ip	3/0/0	21.7	8.9	26.2	0.3
mushroom-best	0/3/0	1.27e07	111.0	49.0	3.6
mzzv11	0/3/0	58.5	20.9	19.2	0.0
mzzv42z	0/3/0	62.7	8.4	20.3	0.0
n2seq36q	3/0/0	99.3	0.7	3.0	0.0
n3div36	3/0/0	99.3	0.4	1.0	0.0
n5-3	0/3/0	37.0	0.4	13.9	0.0
neos-1122047	3/0/0	1.5	1.3	4.2	0.0
neos-1171448	3/0/0	2.9	1.7	31.0	1.0
neos-1171737	3/0/0	7.7	0.6	31.3	1.3
neos-1354092	0/3/0	5.9	231.9	31.2	0.0
neos-1445765	3/0/0	35.2	43.4	11.0	0.0
neos-1456979	0/2/1	121.0	9.7	188.7	29.6
neos-1582420	0/3/0	93.5	2.4	155.1	14.2

(continued)

Table A.30 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
neos-2657525-crna	0/2/1	851.5	0.9	278.4	7.8
neos-2746589-doon	0/3/0	1608.2	379.3	335.4	30.0
neos-2978193-inde	3/0/0	15.3	0.1	2.3	0.0
neos-2987310-joes	0/0/0	0.0	0.1	0.0	0.0
neos-3004026-krka	0/0/0	-	-	-	-
neos-3024952-loue	0/0/3	602.0	140.5	1590.8	1.7
neos-3046615-murg	0/3/0	160.0	0.1	98.7	72.0
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0
neos-3216931-puriri	0/0/2	61.7 <sup>(2)</sup>	1291.7	1034.1	0.0
neos-3381206-awhea	0/0/2	4.9 <sup>(2)</sup>	25.4	1210.3	0.7
neos-3402294-bobin	3/0/0	551.9	14.3	19.2	0.0
neos-3555904-turama	0/0/0	-	-	-	-
neos-3627168-kasai	3/0/0	1.4	0.2	29.2	0.6
neos-3656078-kumeu	0/0/3	677.6	1053.4	868.0	34.7
neos-3754480-nidda	3/0/0	22.1	0.1	68.7	14.7
neos-4300652-rahue	0/1/0	141.1 <sup>(1)</sup>	442.5	79.0	0.0
neos-4338804-snowy	0/3/0	10461.6	0.9	195.2	44.4
neos-4387871-tavua	0/0/2	1742.4 <sup>(2)</sup>	14.4	1213.9	676.0
neos-4413714-turia	2/0/1	4564.5	122.8	228.2	43.9
neos-4532248-waihi	0/1/2	949.4	391.5	458.4	41.7
neos-4647030-tutaki	3/0/0	51.2	14.6	20.4	0.0
neos-4722843-widden	0/3/0	325.2	163.3	226.1	14.3
neos-4738912-atrato	0/3/0	11.3	0.3	12.4	0.0
neos-4763324-toguru	3/0/0	30.7	23.2	21.3	0.0
neos-4954672-berkel	3/0/0	48.8	0.1	32.3	1.6
neos-5049753-cuanza	0/0/0	-	-	-	-
neos-5052403-cygnat	2/0/0	1.6 <sup>(2)</sup>	2128.7	3.0	0.0
neos-5093327-huahum	3/0/0	47.5	7.0	64.7	14.6
neos-5104907-jarama	0/0/0	-	-	-	-
neos-5107597-kakapo	3/0/0	43380.9	2.1	147.0	119.1
neos-5114902-kasavu	0/0/0	-	-	-	-
neos-5188808-nattai	3/0/0	432.9	2.5	26.3	0.0
neos-5195221-niemur	3/0/0	235.5	3.5	7.0	0.0
neos-631710	3/0/0	162.4	1003.1	1.0	0.0
neos-662469	0/3/0	1134.9	4.9	4.0	0.0
neos-787933	3/0/0	166.7	5.5	1.0	0.0
neos-827175	3/0/0	7.1	1.3	1.0	0.0
neos-848589	3/0/0	3.33e05	46.3	69.3	21.3
neos-860300	3/0/0	45.1	0.4	9.0	0.0
neos-873061	3/0/0	50.2	511.3	31.3	1.3
neos-911970	0/3/0	178.8	0.1	51.0	3.8
neos-933966	0/3/0	116.3	13.6	11.7	0.0
neos-950242	3/0/0	152.1	25.4	18.6	0.0
neos-957323	3/0/0	5.2	11.4	1.0	0.0
neos-960392	3/0/0	1.5	18.7	16.8	0.0
neos10	0/3/0	74.7	0.1	2.0	0.0
neos16	0/0/1	1.1 <sup>(1)</sup>	9.6	1084.0	2.0
neos17	3/0/0	265.8	0.1	31.7	1.6
neos20	0/0/3	38.2	5.7	1180.4	72.2
neos5	3/0/0	22.0	0.1	4.0	0.0
neos7	0/3/0	73.3	0.3	54.8	9.8
neos8	0/3/0	100.0	0.1	3.6	0.0
net12	3/0/0	24.2	3.9	22.9	0.0
netdiversion	3/0/0	100.9	71.9	13.1	0.0
nexp-150-20-8-5	3/0/0	175.8	1.3	27.2	0.6
nh97p	0/0/3	7.1	13.1	952.4	271.3
nh97t	0/0/3	9.3	20.2	1249.0	229.7
noswot	0/3/0	20.6	0.1	38.0	1.8
ns1116954	1/1/0	0.0 <sup>(2)</sup>	1273.3	142.2	4.5
ns1208400	0/3/0	126.0	154.4	324.7	0.0
ns1644855	0/3/0	5.5	1351.7	47.7	6.4

(continued)

Table A.30 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
ns1760995	3/0/0	13.7	398.2	78.3	2.6
ns1830653	1/2/0	474.0	8.2	266.4	11.8
ns1952667	0/0/0	-	-	-	-
nsrand-ix	3/0/0	99.1	0.1	1.0	0.0
nu25-pr12	0/3/0	79.5	0.2	18.0	0.0
nursesched-medium-hint03	0/3/0	623.6	46.6	13.5	0.0
nursesched-sprint02	0/3/0	39.7	2.3	9.6	0.0
nw04	3/0/0	21.5	2.5	18.1	0.0
opm2-z10-s4	3/0/0	94.2	91.1	1.0	0.0
opt1217	0/3/0	0.0	0.1	41.8	4.4
p200x1188c	3/0/0	3.9	0.1	31.0	1.0
p2756	3/0/0	121.7	0.1	4.0	0.0
peg-solitaire-a3	0/0/0	-	-	-	-
pg	3/0/0	12.6	0.3	52.0	19.0
pg5-34	3/0/0	7.4	0.4	50.6	12.1
physiciansched3-3	0/3/0	23.5	3175.6	84.4	0.6
physiciansched6-2	0/0/3	91.6	116.8	909.5	0.6
piperout-08	0/0/3	10.8	41.6	1215.2	5.5
piperout-27	0/0/3	64.9	56.8	1033.8	4.1
pk1	3/0/0	1586.3	0.1	59.0	10.7
pp08a	3/0/0	55.8	0.1	15.6	0.0
pp08aCUTS	3/0/0	25.7	0.1	12.0	0.0
proteindesign121hz512p9	0/2/1	5.4	139.4	425.7	17.2
proteindesign122trx11p8	0/2/1	2.5	90.8	309.4	16.0
protfold	3/0/0	67.4	49.9	30.4	0.3
qap10	3/0/0	41.5	26.5	3.0	0.0
qiu	3/0/0	861.2	0.1	5.8	0.3
rB10-011000	3/0/0	238.7	0.6	27.2	0.3
rB10-011001	3/0/0	207.0	0.7	27.6	0.3
rB11-010000	3/0/0	307.8	2.4	30.9	0.6
rB11-110001	3/0/0	169.7	3.5	30.0	0.3
rB12-111111	0/3/0	76.6	10.6	246.8	8.5
rC10-001000	3/0/0	261.2	0.2	26.3	0.0
rC10-100001	3/0/0	489.7	1.7	76.0	1.3
rC11-010100	0/3/0	333.8	2.1	2.0	0.0
rC11-011100	0/3/0	480.5	0.8	2.0	0.0
rC12-100000	3/0/0	485.2	7.3	30.2	1.1
rC12-111100	3/0/0	194.9	0.6	1.0	0.0
radiationm18-12-05	0/3/0	136.2	1.7	73.5	4.3
radiationm40-10-02	0/3/0	171.6	20.0	209.9	28.6
rail01	0/0/0	-	-	-	-
rail02	0/0/0	-	-	-	-
rail507	3/0/0	25.1	4.6	1.0	0.0
ran14x18-disj-8	3/0/0	16.1	0.2	22.0	0.3
rd-rplusc-21	0/0/3	100.3	42.2	829.8	366.0
reblock115	3/0/0	10.9	0.7	48.8	5.7
rmatr100-p10	3/0/0	29.5	1.5	2.3	0.0
rmatr200-p5	3/0/0	19.5	64.2	2.0	0.0
rocl-4-11	0/0/1	33.1 <sup>(1)</sup>	44.3	1043.0	1.0
rocl-5-11	0/0/2	74.1 <sup>(2)</sup>	18.8	757.0	306.9
roi2alpha3n4	3/0/0	66.8	33.1	34.7	2.0
roi5alpha10n8	3/0/0	57.4	429.8	29.3	0.0
roll3000	0/3/0	36.3	0.8	62.7	9.7
rout	0/3/0	13094.3	0.1	35.5	1.7
s100	0/1/0	76.5 <sup>(1)</sup>	2486.1	4.0	0.0
s250r10	0/3/0	0.1	335.1	3.0	0.0
satellites2-40	0/0/0	-	-	-	-
satellites2-60-fs	0/0/0	-	-	-	-
savsched1	0/0/0	-	-	-	-
sct2	3/0/0	9.0	0.2	20.6	0.0
set1ch	3/0/0	56.0	0.1	31.0	1.0

(continued)

Table A.30 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts
seymour	3/0/0	16.1	1.4	1.0	0.0
seymour1	3/0/0	3.5	1.6	8.0	0.0
sing326	3/0/0	59.6	75.8	20.9	0.6
sing44	3/0/0	20.6	74.6	12.1	0.0
snp-02-004-104	0/3/0	21.2	309.1	38.8	3.6
sorrell3	3/0/0	39.9	5.2	1.0	0.0
sp150x300d	3/0/0	1.4	0.1	31.3	1.3
sp97ar	3/0/0	6512.1	2.8	2.4	0.0
sp98ar	3/0/0	698.4	1.5	1.0	0.0
splice1k1	3/0/0	99.4	150.6	12.7	0.0
square41	0/0/0	-	-	-	-
square47	0/0/0	-	-	-	-
supportcase10	3/0/0	122.5	463.1	10.9	0.0
supportcase12	0/3/0	1.4	205.5	21.0	0.0
supportcase18	3/0/0	41.7	1.1	1.0	0.0
supportcase26	3/0/0	323.6	0.1	89.3	62.7
supportcase33	0/3/0	93.5	3.6	107.9	19.1
supportcase40	3/0/0	17.6	1.4	16.6	0.0
supportcase42	0/3/0	2.91e06	14.5	16.9	0.0
supportcase6	3/0/0	0.6	24.6	11.6	0.0
supportcase7	3/0/0	12.2	4.2	25.0	0.0
swath	0/3/0	196.2	3.6	168.2	56.7
swath1	3/0/0	15.0	0.4	31.6	2.1
swath3	3/0/0	13.5	0.6	53.9	12.1
t1717	2/0/0	163.6 <sup>(2)</sup>	321.1	37.5	0.0
tbfp-network	3/0/0	75.4	40.9	11.1	0.0
thor50dday	3/0/0	257.8	161.2	24.5	1.7
timtab1	0/3/0	65.1	0.8	179.6	75.2
timtab2	0/1/2	73.0	7.9	824.5	306.6
tr12-30	3/0/0	72.5	0.1	31.7	1.6
traininstance2	0/0/3	99.5	30.4	1548.9	38.2
traininstance6	0/1/2	311.3	6.3	709.7	98.6
trento1	0/3/0	107.3	33.0	10.3	0.0
triptim1	0/3/0	0.0	77.0	5.5	0.0
uccase12	3/0/0	342.5	261.5	16.7	0.0
uccase9	3/0/0	180.7	54.8	76.9	26.4
uct-subprob	3/0/0	22.3	0.7	10.2	0.0
unitcal-7	0/0/3	31.3	107.2	1270.0	236.3
var-smallemery-m6j6	3/0/0	50.4	17.6	65.5	9.2
vpm2	3/0/0	470.0	0.1	20.4	0.0
wachplan	0/3/0	0.0	1.6	30.1	0.4

Table A.31.: Performance of FP+( $c, \Delta$ ) with SCIP

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	2/1/0	<b>11.0</b>	<b>10.4</b>	<b>184.0</b>	1.1	-52.7/-56.7/-58.5/0.0
30n20b8	0/0/3	<b>325.9</b>	34.6	1122.8	157.1	-15.9/-1.7/2.6/16.4
50v-10	0/3/0	125.3	<b>0.2</b>	<b>19.4</b>	0.3	-8.6/33.3/28.7/0.0
CMS750-4	3/0/0	60.2	<b>1.8</b>	<b>48.2</b>	<b>6.2</b>	0.0/30.8/40.6/62.2
a1c1s1	3/0/0	<b>23.0</b>	<b>0.4</b>	32.0	1.3	26.0/-50.0/-0.9/0.0
academicimetablesmall	0/0/0	-	-	-	-	-/-/-/-
aflow30a	3/0/0	<b>111.7</b>	0.1	<b>29.8</b>	<b>0.8</b>	27.7/0.0/32.3/86.7
aflow40b	3/0/0	<b>196.1</b>	<b>0.2</b>	<b>25.8</b>	<b>1.5</b>	-48.8/33.3/26.5/42.3
air04	3/0/0	<b>1.8</b>	<b>6.2</b>	<b>10.1</b>	0.0	-72.2/-35.5/-15.8/0.0
air05	3/0/0	<b>2.7</b>	1.7	<b>9.1</b>	0.0	25.0/-5.9/-33.0/0.0
app1-1	3/0/0	15.6	0.1	33.9	3.0	0.0/0.0/-1.8/-3.3
app1-2	3/0/0	43.1	2.6	41.2	9.5	0.0/3.7/1.0/5.0
arki001	0/0/3	2.8	<b>49.6</b>	939.1	206.3	0.0/11.3/18.4/19.2

(continued)

Table A.31 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
assign1-5-8	0/3/0	<b>6.4</b>	0.1	<b>6.0</b>	0.0	-70.3/0.0/75.5/0.0
atlanta-ip	3/0/0	<b>26.2</b>	<b>23.1</b>	<b>14.2</b>	<b>0.0</b>	33.7/28.3/72.4/100.0
b1c1s1	3/0/0	<b>104.4</b>	<b>0.2</b>	33.3	3.3	28.3/-50.0/0.0/-9.1
bab2	0/3/0	<b>54.5</b>	<b>538.2</b>	<b>354.3</b>	<b>139.4</b>	-54.5/-39.9/-74.1/-89.5
bab6	1/2/0	<b>43.0</b>	<b>207.4</b>	<b>165.7</b>	<b>38.1</b>	-64.2/-23.6/-62.9/-88.2
beasleyC3	3/0/0	11.6	0.1	35.0	4.8	5.7/0.0/0.0/0.0
binkar10-1	3/0/0	<b>2.5</b>	0.1	<b>11.1</b>	0.0	40.5/0.0/-41.4/0.0
blp-ar98	3/0/0	<b>75.7</b>	<b>1.8</b>	21.5	<b>0.8</b>	13.7/-11.1/-1.9/-12.5
blp-ic98	3/0/0	51.9	0.2	1.0	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/0	-	-	-	-	-/-/-/-
bppc4-08	0/3/0	41.2	<b>0.2</b>	<b>6.0</b>	<b>0.0</b>	-6.1/60.0/89.9/100.0
brazil3	0/3/0	<b>1123.5</b>	<b>105.2</b>	<b>50.5</b>	<b>0.3</b>	-41.3/-54.8/-36.0/-100.0
buildingenergy	0/3/0	1.1	893.6	3.0	0.0	-/-/-/-
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	<b>0.0</b>	2.3	33.5	<b>2.3</b>	100.0/-8.7/-7.5/-56.5
chromaticindex1024-7	3/0/0	0.0	<b>2286.9</b>	<b>5.0</b>	0.0	0.0/-68.9/-60.0/0.0
chromaticindex512-7	3/0/0	0.0	157.7	<b>1.9</b>	0.0	0.0/-9.6/-31.6/0.0
cmflsp50-24-8-8	0/0/2	16.8	86.1	784.3	213.6	-/-/-/-
co-100	3/0/0	<b>55197.0</b>	2.4	13.3	0.0	-19.3/-4.2/-5.3/0.0
cod105	3/0/0	100.0	15.6	1.0	0.0	0.0/-0.6/0.0/0.0
comp07-2idx	0/3/0	<b>2724.8</b>	<b>34.8</b>	<b>51.3</b>	<b>1.3</b>	20.9/-57.8/-58.5/-100.0
comp21-2idx	0/3/0	<b>395.0</b>	<b>12.1</b>	<b>58.6</b>	<b>0.3</b>	19.0/-29.8/-57.7/-100.0
cost266-UUE	0/0/3	<b>105.8</b>	0.2	5.8	0.0	-28.2/0.0/48.7/0.0
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/0/3	<b>95.9</b>	<b>217.3</b>	852.2	10.0	-21.7/-33.0/-28.8/59.8
csched008	0/2/1	9.4	<b>13.4</b>	198.7	16.9	-2.1/-46.3/-26.8/7.1
cvs16r128-89	3/0/0	97.9	3.3	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	64.6	<b>2.0</b>	0.0	0.0/-5.6/87.7/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>97.4</b>	<b>2.0</b>	<b>0.0</b>	-66.7/17.1/93.2/100.0
dano3mip	3/0/0	<b>15.4</b>	<b>141.0</b>	<b>5.0</b>	<b>0.0</b>	36.4/67.8/93.0/100.0
danoit	3/0/0	<b>15.4</b>	<b>0.5</b>	<b>37.8</b>	<b>3.0</b>	36.9/87.5/70.5/93.6
disctom	3/0/0	0.0	6.2	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	149.8	1.2	36.0	<b>0.8</b>	-3.9/-8.3/-7.8/-50.0
drayage-25-23	3/0/0	178.6	1.6	42.8	<b>0.4</b>	-4.2/-6.3/-4.4/69.2
ds	0/0/0	-	-	-	-	-/-/-/-
dws008-01	0/0/1	17.4	18.8	697.0	200.0	-/-/-/-
eil33-2	2/1/0	<b>77.9</b>	<b>1.7</b>	<b>78.7</b>	<b>5.9</b>	-32.1/-64.7/-61.0/-93.2
eilA101-2	0/2/1	<b>255.1</b>	1042.4	534.7	4.6	-33.6/2.5/3.6/42.5
enlight-hard	0/0/0	-	-	-	-	-/-/-/-
exp-1-500-5-5	3/0/0	<b>135.5</b>	0.1	<b>15.5</b>	0.0	-48.1/0.0/42.4/0.0
fast0507	3/0/0	24.2	4.6	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	0/0/3	2714.2	18.4	742.8	125.8	0.0/5.2/2.9/17.5
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>11.3</b>	<b>5.0</b>	<b>42.8</b>	<b>2.2</b>	-18.6/34.2/42.2/58.5
fiber	3/0/0	27192.6	0.1	1.0	0.0	0.0/0.0/0.0/0.0
fixnet6	3/0/0	<b>34.7</b>	0.1	31.0	1.0	-20.2/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	11.3	0.1	2.9	0.0	-7.1/0.0/0.0/0.0
germanrr	0/3/0	4.7	<b>6.2</b>	<b>41.2</b>	<b>2.6</b>	-8.5/23.5/12.7/46.9
gesa2	0/3/0	2.4	0.1	20.4	0.0	-8.3/0.0/0.0/0.0
gesa2-o	0/3/0	<b>8.4</b>	0.1	32.0	1.3	-19.0/0.0/-0.9/0.0
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.4	1.0	0.0	0.0/0.0/0.0/0.0
glass4	3/0/0	<b>207.6</b>	0.1	<b>11.0</b>	<b>0.0</b>	23.5/0.0/87.9/100.0
gmu-35-40	3/0/0	<b>7.4</b>	0.1	<b>3.0</b>	<b>0.0</b>	38.8/0.0/92.9/100.0
gmu-35-50	3/0/0	<b>10.8</b>	0.1	<b>34.9</b>	<b>1.9</b>	25.0/0.0/11.9/51.3
graph20-20-1rand	3/0/0	<b>5.6</b>	<b>1.7</b>	<b>15.5</b>	0.0	83.8/39.3/39.5/0.0
graphdraw-domain	0/3/0	36.0	0.1	<b>61.8</b>	<b>25.7</b>	1.4/0.0/17.2/-32.7
h80x6320d	3/0/0	<b>34.3</b>	0.9	33.3	2.2	-11.7/0.0/0.0/0.0
harp2	3/0/0	12.3	0.1	<b>16.8</b>	0.0	-4.9/0.0/-17.3/0.0
highschool1-aigio	0/0/0	-	-	-	-	-/-/-/-

(continued)

Table A.31 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
hypothyroid-k1	2/1/0	98.8	23.3	72.9	<b>11.7</b>	-2.7/4.1/-0.3/19.3
ic97p	0/0/3	13.3	<b>3.3</b>	782.0	175.2	8.3/19.5/-5.0/-2.5
ic97t	0/0/3	12.9	3.1	896.2	228.1	-/-/-/-
icir97p	0/0/0	-	-	-	-	-/-/-/-
icir97t	0/2/1	13.4	<b>10.7</b>	479.4	311.5	0.0/57.9/31.7/34.0
irish-electricity	3/0/0	<b>9.1</b>	56.8	<b>31.0</b>	<b>2.1</b>	-37.4/-0.4/12.7/-14.3
irp	3/0/0	<b>6.8</b>	<b>0.7</b>	<b>16.6</b>	<b>0.0</b>	-14.7/22.2/19.8/100.0
istanbul-no-cutoff	3/0/0	<b>42.0</b>	<b>12.5</b>	<b>12.7</b>	0.0	-95.7/-35.2/-44.9/0.0
k1mushroom	3/0/0	18.2	83.7	1.0	0.0	0.0/0.7/0.0/0.0
lectsched-5-obj	0/0/0	-	-	-	-	-/-/-/-
leo1	3/0/0	842.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	7522.4	0.4	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>301.9</b>	<b>0.1</b>	<b>13.3</b>	<b>0.0</b>	55.3/83.3/85.7/100.0
lotsize	3/0/0	<b>157.3</b>	0.3	<b>42.0</b>	<b>7.3</b>	-59.9/0.0/11.8/27.7
mad	3/0/0	7890.2	0.1	<b>15.0</b>	0.0	0.8/0.0/-20.0/0.0
manna81	0/3/0	1.2	0.2	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>66.2</b>	<b>24.9</b>	<b>8.0</b>	<b>0.0</b>	-62.5/53.5/81.3/100.0
map16715-04	3/0/0	85.0	<b>31.5</b>	<b>8.7</b>	<b>0.0</b>	8.9/52.6/78.9/100.0
markshare1	3/0/0	44679.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	58088.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	6400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	3/0/0	<b>35.2</b>	0.1	<b>7.0</b>	<b>0.0</b>	52.6/0.0/92.1/100.0
mas76	3/0/0	<b>9.8</b>	0.1	<b>3.6</b>	<b>0.0</b>	71.8/0.0/96.0/100.0
mc11	3/0/0	112.8	0.3	43.0	13.0	-4.1/0.0/-1.6/-5.4
mcsched	3/0/0	<b>23.7</b>	0.4	<b>4.3</b>	0.0	-29.5/0.0/-16.3/0.0
mik-250-20-75-4	0/3/0	<b>2.2</b>	0.1	<b>6.3</b>	<b>0.0</b>	96.4/0.0/83.6/100.0
milo-v12-6-r2-40-1	0/0/3	95.0	25.9	960.0	0.0	-0.9/-7.3/-7.3/0.0
misc07	3/0/0	69.7	0.1	<b>20.9</b>	<b>0.0</b>	1.0/0.0/28.2/100.0
mkc	3/0/0	26698.7	<b>0.1</b>	<b>6.0</b>	0.0	-2.8/50.0/50.0/0.0
mod011	3/0/0	<b>11.6</b>	<b>0.1</b>	<b>5.0</b>	0.0	-11.2/50.0/75.2/0.0
modglob	3/0/0	<b>50.8</b>	0.1	<b>5.6</b>	<b>0.0</b>	-99.4/0.0/82.1/100.0
momentum1	1/1/1	217.6	<b>14.2</b>	361.2	234.5	6.5/-14.8/-13.6/-15.4
msc98-ip	3/0/0	<b>18.6</b>	<b>6.8</b>	25.7	0.3	14.3/23.6/1.9/0.0
mushroom-best	0/3/0	1.18e07	<b>294.3</b>	<b>106.6</b>	<b>54.7</b>	7.1/-62.3/-54.0/-93.4
mzzv11	0/3/0	58.3	20.5	<b>11.6</b>	0.0	0.3/1.9/39.6/0.0
mzzv42z	0/3/0	62.1	<b>7.4</b>	<b>8.5</b>	0.0	1.0/11.9/58.1/0.0
n2seq36q	3/0/0	99.4	<b>0.8</b>	3.3	0.0	-0.1/-12.5/-9.1/0.0
n3div36	3/0/0	99.3	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	33.5	<b>0.3</b>	13.0	0.0	9.5/25.0/6.5/0.0
neos-1122047	3/0/0	1.5	1.3	<b>2.6</b>	0.0	0.0/0.0/38.1/0.0
neos-1171448	3/0/0	<b>5.8</b>	<b>0.6</b>	<b>3.9</b>	<b>0.0</b>	-50.0/64.7/87.4/100.0
neos-1171737	3/0/0	<b>12.9</b>	<b>0.2</b>	<b>3.8</b>	<b>0.0</b>	-40.3/66.7/87.9/100.0
neos-1354092	0/3/0	<b>18.7</b>	236.3	30.5	0.0	-68.4/-1.9/2.2/0.0
neos-1445765	3/0/0	<b>40.4</b>	<b>33.9</b>	10.3	0.0	-12.9/21.9/6.4/0.0
neos-1456979	0/1/2	121.1	<b>12.6</b>	309.5	23.8	-0.1/-23.0/-39.0/19.6
neos-1582420	0/3/0	<b>67.4</b>	<b>1.0</b>	<b>62.0</b>	<b>5.7</b>	27.9/58.3/60.0/59.9
neos-2657525-crna	0/3/0	<b>1243.3</b>	<b>1.4</b>	505.0	9.8	-31.5/-35.7/-44.9/-20.4
neos-2746589-doon	0/3/0	<b>1312.0</b>	<b>102.8</b>	<b>198.7</b>	27.4	18.4/72.9/40.8/8.7
neos-2978193-inde	3/0/0	<b>5.3</b>	<b>0.2</b>	<b>3.9</b>	0.0	65.4/-50.0/-41.0/0.0
neos-2987310-joes	0/0/0	0.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-3004026-krka	0/0/0	-	-	-	-	-/-/-/-
neos-3024952-loue	0/0/3	618.5	<b>167.5</b>	2000.0	4.8	-2.7/-16.1/-20.5/-64.6
neos-3046615-murg	0/3/0	<b>43.8</b>	<b>0.2</b>	<b>151.0</b>	<b>61.5</b>	72.6/-50.0/-34.6/14.6
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/3	61.4	1247.4	1036.8	0.3	-/-/-/-
neos-3381206-awhea	0/0/3	4.9	15.6	768.9	0.6	-/-/-/-
neos-3402294-bobin	3/0/0	<b>135.9</b>	<b>6.0</b>	<b>10.6</b>	0.0	75.4/58.0/44.8/0.0
neos-3555904-turama	0/0/0	-	-	-	-	-/-/-/-
neos-3627168-kasai	3/0/0	<b>1.2</b>	<b>0.1</b>	<b>22.0</b>	<b>0.3</b>	14.3/50.0/24.7/50.0
neos-3656078-kumeu	0/0/3	684.6	<b>1417.7</b>	914.6	20.8	-1.0/-25.7/-5.1/40.1
neos-3754480-nidda	3/0/0	<b>29.6</b>	0.1	<b>10.3</b>	<b>0.0</b>	-25.3/0.0/85.0/100.0

(continued)

Table A.31 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-4300652-rahue	0/0/1	300.3	3479.5	717.0	0.0	-/-/-/-
neos-4338804-snowy	0/3/0	<b>54509.9</b>	<b>0.4</b>	<b>125.6</b>	<b>39.3</b>	-80.8/55.6/35.7/11.5
neos-4387871-tavua	0/0/3	745.9	10.0	929.8	505.2	-/-/-/-
neos-4413714-turia	3/0/0	<b>797.3</b>	<b>14.4</b>	11.0	0.0	82.5/88.3/95.2/100.0
neos-4532248-waihi	0/0/3	949.4	<b>786.2</b>	727.3	20.1	0.0/-50.2/-37.0/51.8
neos-4647030-tutaki	3/0/0	<b>109.4</b>	<b>11.9</b>	<b>13.0</b>	0.0	-53.2/18.5/36.3/0.0
neos-4722843-widden	0/3/0	354.5	<b>93.6</b>	<b>149.3</b>	<b>8.9</b>	-8.3/42.7/34.0/37.8
neos-4738912-atrato	0/3/0	10.4	0.3	<b>8.9</b>	0.0	8.0/0.0/28.2/0.0
neos-4763324-toguru	3/0/0	<b>50.6</b>	21.9	<b>8.0</b>	0.0	-39.3/5.6/62.4/0.0
neos-4954672-berkel	3/0/0	47.9	0.1	<b>11.5</b>	<b>0.0</b>	1.8/0.0/64.4/100.0
neos-5049753-cuanza	0/0/0	-	-	-	-	-/-/-/-
neos-5052403-cygnnet	1/0/2	6.0	2734.7	3.6	0.0	-/-/-/-
neos-5093327-huahum	3/0/0	<b>74.7</b>	<b>4.0</b>	<b>43.1</b>	<b>5.4</b>	-36.4/42.9/33.4/63.0
neos-5104907-jarama	0/0/0	-	-	-	-	-/-/-/-
neos-5107597-kakapo	2/1/0	43341.6	1.9	140.3	109.4	0.1/9.5/4.6/8.1
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	<b>736.3</b>	<b>2.0</b>	<b>16.4</b>	0.0	-41.2/20.0/37.6/0.0
neos-5195221-niemur	3/0/0	<b>452.9</b>	<b>6.4</b>	<b>4.8</b>	0.0	-48.0/-45.3/31.4/0.0
neos-631710	3/0/0	162.4	994.3	1.0	0.0	0.0/0.9/0.0/0.0
neos-662469	0/3/0	1211.0	5.0	4.0	0.0	-6.3/-2.0/0.0/0.0
neos-787933	3/0/0	166.7	5.5	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	7.1	1.3	1.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>4.58e05</b>	51.1	73.3	23.3	-27.3/-9.4/-5.5/-8.6
neos-860300	3/0/0	42.5	<b>0.7</b>	<b>15.6</b>	0.0	5.8/-42.9/-42.3/0.0
neos-873061	3/0/0	53.5	487.3	31.3	1.3	-6.2/4.7/0.0/0.0
neos-911970	0/3/0	<b>260.0</b>	0.1	<b>22.0</b>	<b>0.0</b>	-31.2/0.0/56.9/100.0
neos-933966	0/3/0	<b>77.3</b>	<b>18.0</b>	<b>13.8</b>	0.0	33.5/-24.4/-15.2/0.0
neos-950242	3/0/0	<b>4.3</b>	<b>18.3</b>	<b>22.3</b>	0.0	97.2/28.0/-16.6/0.0
neos-957323	3/0/0	5.2	11.5	1.0	0.0	0.0/-0.9/0.0/0.0
neos-960392	3/0/0	<b>2.4</b>	18.8	<b>28.4</b>	0.0	-37.5/-0.5/-40.8/0.0
neos10	0/3/0	74.7	0.1	2.0	0.0	0.0/0.0/0.0/0.0
neos16	0/0/2	2.4	8.8	1016.0	7.9	-/-/-/-
neos17	3/0/0	261.3	0.1	34.9	<b>2.7</b>	1.7/0.0/-9.2/-40.7
neos20	0/0/3	38.2	<b>5.1</b>	1033.5	55.6	0.0/10.5/12.4/23.0
neos5	3/0/0	21.5	0.1	<b>2.7</b>	0.0	2.3/0.0/32.5/0.0
neos7	0/3/0	<b>34.3</b>	<b>0.2</b>	<b>14.9</b>	<b>0.8</b>	53.2/33.3/72.8/91.8
neos8	0/3/0	100.0	0.1	3.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>34.9</b>	3.8	<b>20.3</b>	0.0	-30.7/2.6/11.4/0.0
netdiversion	3/0/0	<b>77.8</b>	<b>523.4</b>	12.9	0.0	22.9/-86.3/1.5/0.0
nexp-150-20-8-5	3/0/0	165.5	<b>1.6</b>	<b>31.3</b>	<b>0.3</b>	5.9/-18.8/-13.1/50.0
nh97p	0/0/1	9.0	23.9	1956.0	598.0	-/-/-/-
nh97t	0/0/3	9.8	<b>12.9</b>	1015.0	209.3	-5.1/36.1/18.7/8.9
noswot	0/3/0	<b>3.9</b>	0.1	<b>9.9</b>	<b>0.4</b>	81.1/0.0/73.9/77.8
ns1116954	1/1/0	0.0	1280.6	142.2	4.5	-/-/-/-
ns1208400	3/0/0	126.0	<b>50.2</b>	<b>107.2</b>	0.0	0.0/67.5/67.0/0.0
ns1644855	0/3/0	<b>28.3</b>	<b>440.0</b>	<b>6.0</b>	<b>0.0</b>	-80.6/67.4/87.4/100.0
ns1760995	3/0/0	<b>18.4</b>	<b>153.4</b>	<b>20.1</b>	<b>0.3</b>	-25.5/61.5/74.3/88.5
ns1830653	1/1/1	438.5	<b>11.3</b>	260.5	10.3	7.5/-27.4/2.2/12.7
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ipx	3/0/0	99.1	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	79.6	<b>0.1</b>	<b>3.0</b>	0.0	-0.1/50.0/83.3/0.0
nursesched-medium-hint03	0/3/0	<b>1150.1</b>	<b>187.3</b>	<b>32.3</b>	0.0	-45.8/-75.1/-58.2/0.0
nursesched-sprint02	0/3/0	<b>29.3</b>	2.4	<b>11.6</b>	0.0	26.2/-4.2/-17.2/0.0
nw04	3/0/0	<b>28.5</b>	<b>1.2</b>	<b>7.8</b>	0.0	-24.6/52.0/56.9/0.0
opm2-z10-s4	3/0/0	94.2	92.2	1.0	0.0	0.0/-1.2/0.0/0.0
opt1217	0/3/0	<b>1.4</b>	0.1	<b>5.3</b>	<b>0.0</b>	-100.0/0.0/87.3/100.0
p200x1188c	3/0/0	3.9	0.1	31.0	1.0	0.0/0.0/0.0/0.0
p2756	3/0/0	121.2	0.1	<b>3.0</b>	0.0	0.4/0.0/25.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/-
pg	3/0/0	<b>18.9</b>	<b>0.1</b>	<b>9.7</b>	<b>0.0</b>	-33.3/66.7/81.3/100.0
pg5-34	3/0/0	<b>6.4</b>	<b>0.1</b>	<b>6.8</b>	<b>0.0</b>	13.5/75.0/86.6/100.0

(continued)



Table A.31 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
physiciansched3-3	0/0/0	-	-	-	-	-/-/-/-
physiciansched6-2	0/0/3	124.9	157.2	1297.6	2.4	-26.7/-25.7/-29.9/-75.0
piperout-08	0/0/3	40.0	48.6	1478.9	5.4	-73.0/-14.4/-17.8/1.8
piperout-27	0/0/2	94.9	76.8	1363.6	0.0	-/-/-/-
pk1	3/0/0	424.7	0.1	31.9	0.3	73.2/0.0/45.9/97.2
pp08a	3/0/0	76.3	0.1	19.3	0.0	-26.9/0.0/-19.2/0.0
pp08aCUTS	3/0/0	19.4	0.1	15.1	0.0	24.5/0.0/-20.5/0.0
proteindesign121hz512p9	0/3/0	10.5	41.6	162.7	7.8	-48.6/70.2/61.8/54.7
proteindesign122trx11p8	0/0/3	6.6	379.7	808.8	15.7	-62.1/-76.1/-61.7/1.9
protfold	3/0/0	65.8	40.1	29.1	0.3	2.4/19.6/4.3/0.0
qap10	3/0/0	50.0	26.7	4.0	0.0	-17.0/-0.7/-25.0/0.0
qiu	3/0/0	1563.9	0.1	3.3	0.0	-44.9/0.0/43.1/100.0
rB10-011000	3/0/0	262.4	0.6	28.3	0.3	-9.0/0.0/-3.9/0.0
rB10-011001	3/0/0	215.4	0.7	25.4	0.3	-3.9/0.0/8.0/0.0
rB11-010000	3/0/0	341.2	2.2	20.2	0.0	-9.8/8.3/34.6/100.0
rB11-110001	3/0/0	210.1	3.4	21.4	0.0	-19.2/2.9/28.7/100.0
rB12-111111	0/2/1	81.3	28.5	737.3	9.7	-5.8/-62.8/-66.5/-12.4
rC10-001000	3/0/0	270.1	0.2	27.6	0.0	-3.3/0.0/-4.7/0.0
rC10-100001	2/1/0	527.3	2.3	118.2	1.7	-7.1/-26.1/-35.7/-23.5
rC11-010100	0/3/0	333.8	2.1	2.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	0/3/0	480.5	0.8	2.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	315.7	7.6	39.1	1.1	34.9/-3.9/-22.8/0.0
rC12-111100	3/0/0	194.9	0.6	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	179.2	1.6	66.5	2.8	-24.0/5.9/9.5/34.9
radiationm40-10-02	0/3/0	148.0	19.2	185.6	24.3	13.8/4.0/11.6/15.0
rail01	0/0/0	-	-	-	-	-/-/-/-
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	25.1	4.6	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	19.3	0.2	23.3	0.6	-16.6/0.0/-5.6/-50.0
rd-rplusc-21	0/0/3	101.4	36.7	615.5	262.9	-1.1/13.0/25.8/28.2
reblock115	3/0/0	16.9	0.6	25.8	0.6	-35.5/14.3/47.1/89.5
rmatr100-p10	3/0/0	2.2	1.4	4.3	0.0	92.5/6.7/-46.5/0.0
rmatr200-p5	3/0/0	19.9	80.9	6.0	0.0	-2.0/-20.6/-66.7/0.0
rocl-4-11	0/0/1	66.4	30.9	791.0	1.0	-/-/-/-
rocll-5-11	0/1/2	90.6	24.4	847.2	340.6	-/-/-/-
roi2alpha3n4	3/0/0	48.9	5.2	6.0	0.0	26.8/84.3/82.7/100.0
roi5alpha10n8	3/0/0	53.5	80.7	7.0	0.0	6.8/81.2/76.1/0.0
roll3000	0/3/0	41.8	0.8	76.0	13.1	-13.2/0.0/-17.5/-26.0
rout	0/3/0	13203.0	0.1	32.3	0.6	-0.8/0.0/9.0/64.7
s100	1/2/0	43.4	2370.9	6.0	0.0	-/-/-/-
s250r10	0/3/0	0.1	333.5	3.0	0.0	0.0/0.5/0.0/0.0
satellites2-40	0/0/0	-	-	-	-	-/-/-/-
satellites2-60-fs	0/0/0	-	-	-	-	-/-/-/-
savsched1	0/0/0	-	-	-	-	-/-/-/-
sct2	3/0/0	20.7	0.1	4.6	0.0	-56.5/50.0/77.7/0.0
set1ch	3/0/0	22.8	0.1	31.0	1.0	59.3/0.0/0.0/0.0
seymour	3/0/0	16.1	1.4	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	4.5	1.7	3.3	0.0	-22.2/-5.9/58.8/0.0
sing326	3/0/0	57.0	75.5	14.5	0.3	4.4/0.4/30.6/50.0
sing44	3/0/0	21.7	73.2	5.1	0.0	-5.1/1.9/57.9/0.0
snp-02-004-104	0/3/0	74.1	57.0	33.3	1.0	-71.4/81.6/14.2/72.2
sorrell3	3/0/0	39.9	5.2	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	1.4	0.1	31.3	1.3	0.0/0.0/0.0/0.0
sp97ar	3/0/0	6420.0	2.8	2.2	0.0	1.4/0.0/8.3/0.0
sp98ar	3/0/0	698.4	1.5	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.0	131.8	9.0	0.0	0.4/12.5/29.1/0.0
square41	0/0/0	-	-	-	-	-/-/-/-
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	47.2	400.9	11.0	0.0	61.5/13.4/-0.9/0.0
supportcase12	0/3/0	4.6	37.6	3.6	0.0	-69.6/81.7/82.9/0.0
supportcase18	3/0/0	41.7	1.1	1.0	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.31 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
supportcase26	3/0/0	<b>54.6</b>	0.1	<b>7.0</b>	<b>0.0</b>	83.1/0.0/92.2/100.0
supportcase33	0/3/0	94.1	<b>4.3</b>	<b>135.6</b>	<b>31.2</b>	-0.6/-16.3/-20.4/-38.8
supportcase40	3/0/0	<b>49.2</b>	<b>1.1</b>	<b>7.7</b>	0.0	-64.2/21.4/53.6/0.0
supportcase42	0/3/0	<b>5.47e11</b>	<b>83.5</b>	<b>89.0</b>	0.0	-100.0/-82.6/-81.0/0.0
supportcase6	3/0/0	<b>0.5</b>	<b>17.9</b>	<b>4.0</b>	0.0	16.7/27.2/65.5/0.0
supportcase7	3/0/0	12.4	<b>3.5</b>	<b>8.5</b>	0.0	-1.6/16.7/66.0/0.0
swath	1/2/0	191.6	<b>2.7</b>	<b>117.8</b>	<b>35.0</b>	2.3/25.0/30.0/38.3
swath1	3/0/0	<b>28.4</b>	<b>0.6</b>	<b>58.3</b>	<b>14.3</b>	-47.2/-33.3/-45.8/-85.3
swath3	3/0/0	<b>17.2</b>	<b>0.7</b>	<b>60.3</b>	<b>15.3</b>	-21.5/-14.3/-10.6/-20.9
t1717	2/0/0	95.2	174.0	22.7	0.0	-/-/-/-
tbfp-network	3/0/0	<b>8.8</b>	39.4	11.1	0.0	88.3/3.7/0.0/0.0
thor50dday	3/0/0	<b>303.3</b>	<b>186.0</b>	25.3	<b>1.9</b>	-15.0/-13.3/-3.2/-10.5
timtab1	0/3/0	60.2	<b>0.7</b>	<b>213.9</b>	<b>88.1</b>	7.5/12.5/-16.0/-14.6
timtab2	0/0/3	<b>65.5</b>	<b>5.7</b>	890.8	345.6	10.3/27.8/-7.4/-11.3
tr12-30	3/0/0	<b>54.6</b>	0.1	30.2	<b>1.2</b>	24.7/0.0/4.7/25.0
traininstance2	0/1/2	<b>55.2</b>	28.7	1655.2	51.1	44.5/5.6/-6.4/-25.2
traininstance6	0/1/2	311.3	6.3	709.7	98.6	0.0/0.0/0.0/0.0
trento1	0/3/0	<b>6.3</b>	<b>50.2</b>	<b>6.3</b>	0.0	94.1/-34.3/38.8/0.0
triptim1	0/3/0	<b>0.2</b>	71.8	<b>3.0</b>	0.0	-100.0/6.8/45.5/0.0
uccase12	3/0/0	337.6	262.7	<b>15.0</b>	0.0	1.4/-0.5/10.2/0.0
uccase9	3/0/0	191.8	<b>42.6</b>	<b>21.6</b>	<b>0.8</b>	-5.8/22.3/71.9/97.0
uct-subprob	3/0/0	<b>19.5</b>	<b>0.6</b>	10.5	0.0	12.6/14.3/-2.9/0.0
unitcal-7	0/1/2	<b>24.7</b>	<b>74.0</b>	882.3	153.8	21.1/31.0/30.5/34.9
var-smallemery-m6j6	3/0/0	<b>22.5</b>	<b>5.1</b>	<b>5.3</b>	<b>0.0</b>	55.4/71.0/91.9/100.0
vpm2	3/0/0	460.3	0.1	20.4	0.0	2.1/0.0/0.0/0.0
wachplan	0/3/0	0.0	<b>1.3</b>	<b>19.6</b>	<b>0.0</b>	0.0/18.8/34.9/100.0
Geom. means			(241 instances)	(211 instances)		
FP		64.0	5.8	17.2	1.3	
FP+(c,Δ)		<b>66.5</b>	<b>5.5</b>	<b>12.1</b>	<b>0.7</b>	

Table A.32.: Performance of FP+(3,sv,g) with SCIP

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	3/0/0	<b>3.1</b>	<b>1.2</b>	<b>36.0</b>	<b>0.3</b>	40.4/73.3/52.9/72.7
30n20b8	0/2/1	<b>199.5</b>	<b>21.1</b>	858.7	213.3	27.2/37.9/25.5/-11.9
50v-10	0/3/0	121.8	0.3	<b>20.4</b>	<b>0.0</b>	-6.0/0.0/25.0/100.0
CMS750-4	3/0/0	<b>85.4</b>	<b>4.8</b>	<b>160.5</b>	<b>36.6</b>	-29.5/-45.8/-49.4/-55.2
a1c1s1	3/0/0	<b>25.0</b>	0.2	32.3	<b>1.9</b>	19.6/0.0/-1.9/-31.6
academictimetablesmall	0/0/1	inf	2460.1	788.0	0.0	-/-/-/-
aflow30a	3/0/0	<b>111.6</b>	0.1	<b>39.5</b>	<b>3.6</b>	27.7/0.0/10.2/40.0
aflow40b	3/0/0	<b>70.9</b>	0.3	<b>39.2</b>	<b>4.4</b>	29.4/0.0/-10.5/-40.9
air04	3/0/0	<b>1.0</b>	<b>4.5</b>	<b>12.4</b>	0.0	-50.0/-11.1/-31.5/0.0
air05	3/0/0	<b>2.9</b>	1.6	<b>4.0</b>	0.0	19.4/0.0/34.4/0.0
app1-1	3/0/0	<b>53.0</b>	<b>0.2</b>	<b>48.9</b>	<b>8.9</b>	-70.6/-50.0/-31.9/-67.4
app1-2	3/0/0	41.5	<b>3.1</b>	<b>46.9</b>	<b>13.8</b>	3.7/-12.9/-11.3/-27.5
arki001	0/2/1	<b>2.0</b>	<b>27.5</b>	769.3	225.1	28.6/50.8/33.2/11.8
assign1-5-8	0/3/0	2.0	0.1	22.3	0.0	-5.0/0.0/9.0/0.0
atlanta-ip	3/0/0	<b>13.9</b>	<b>25.8</b>	<b>30.0</b>	<b>0.3</b>	64.8/19.9/41.6/87.0
b1c1s1	3/0/0	<b>125.3</b>	<b>0.2</b>	33.3	3.3	13.9/-50.0/0.0/-9.1
bab2	1/0/2	<b>13.2</b>	<b>570.7</b>	319.6	30.6	46.8/-43.3/-71.3/-52.0
bab6	1/1/1	<b>23.9</b>	<b>313.1</b>	258.9	23.4	-35.6/-49.4/-76.2/-80.8
beasleyC3	3/0/0	11.8	0.1	35.7	<b>5.6</b>	4.1/0.0/-2.0/-14.3
binkar10-1	3/0/0	4.2	0.1	<b>5.3</b>	0.0	0.0/0.0/18.5/0.0
blp-ar98	3/0/0	<b>68.6</b>	1.5	19.7	<b>0.0</b>	21.8/6.3/6.6/100.0
blp-ic98	3/0/0	51.9	0.2	1.0	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/0	-	-	-	-	-/-/-/-
bppc4-08	0/3/0	<b>31.4</b>	0.5	63.7	8.3	18.9/0.0/-6.9/4.6

(continued)

Table A.32 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
brazil3	0/3/0	<b>545.3</b>	<b>34.8</b>	<b>27.5</b>	0.0	17.4/26.9/14.9/0.0
buildingenergy	0/2/0	1.0	3489.1	11.5	0.0	-/-/-/-
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	inf	2.2	31.7	<b>1.3</b>	0.0/-4.5/-2.2/-23.1
chromaticindex1024-7	3/0/0	0.0	739.4	2.0	0.0	0.0/-3.9/0.0/0.0
chromaticindex512-7	3/0/0	0.0	140.4	1.3	0.0	0.0/1.5/0.0/0.0
cmflsp50-24-8-8	2/1/0	17.3	17.2	201.8	52.9	-/-/-/-
co-100	3/0/0	44546.1	2.3	12.6	0.0	0.0/0.0/0.0/0.0
cod105	3/0/0	100.0	15.6	1.0	0.0	0.0/-0.6/0.0/0.0
comp07-2idx	0/3/0	3687.3	14.6	<b>25.3</b>	0.0	-6.6/0.7/-15.8/0.0
comp21-2idx	0/3/0	511.8	<b>6.3</b>	<b>29.7</b>	<b>0.3</b>	-4.7/25.9/-16.5/-100.0
cost266-UUE	0/0/3	<b>105.8</b>	0.2	8.6	0.0	-28.2/0.0/23.9/0.0
cryptanalysiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/3/0	76.6	<b>53.9</b>	458.9	13.5	-2.0/63.0/24.3/45.8
csched008	0/3/0	8.6	<b>8.5</b>	<b>265.0</b>	<b>32.3</b>	6.5/-15.3/-45.1/-43.7
cvs16r128-89	3/0/0	97.9	3.3	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	60.9	16.6	0.0	0.0/0.2/-2.4/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>171.8</b>	<b>45.4</b>	<b>6.9</b>	-66.7/-31.6/-34.8/-88.4
dano3mip	3/0/0	<b>12.0</b>	<b>275.3</b>	71.0	<b>15.0</b>	50.4/37.2/1.0/19.4
danoint	1/2/0	<b>29.6</b>	<b>1.5</b>	<b>146.6</b>	<b>57.9</b>	-17.6/62.5/-12.5/-19.3
disctom	3/0/0	0.0	6.2	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>122.2</b>	<b>1.3</b>	<b>42.0</b>	<b>1.9</b>	15.1/-15.4/-21.0/-78.9
drayage-25-23	3/0/0	<b>112.6</b>	<b>1.7</b>	<b>55.4</b>	<b>0.6</b>	34.2/-11.8/-26.2/53.8
ds	0/0/0	-	-	-	-	-/-/-/-
dws008-01	0/0/1	21.9	21.0	713.0	199.0	-/-/-/-
eil33-2	0/0/3	<b>440.7</b>	<b>14.4</b>	696.2	184.0	-88.0/-95.8/-95.6/-99.8
eilA101-2	0/1/2	<b>211.2</b>	<b>1567.7</b>	834.1	36.6	-19.7/-31.8/-33.5/-78.1
enlight-hard	0/0/0	-	-	-	-	-/-/-/-
exp-1-500-5-5	3/0/0	<b>50.0</b>	0.1	27.2	<b>0.3</b>	28.9/0.0/-1.1/-100.0
fast0507	3/0/0	24.2	4.6	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	0/0/3	2714.2	<b>22.1</b>	857.0	163.7	0.0/-12.2/-10.7/-6.9
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>8.2</b>	<b>13.2</b>	<b>129.0</b>	<b>13.2</b>	10.9/-42.4/-42.6/-59.8
fiber	3/0/0	27192.6	0.1	1.0	0.0	0.0/0.0/0.0/0.0
fixnet6	3/0/0	25.2	0.1	31.0	1.0	9.0/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	11.1	0.1	<b>3.8</b>	0.0	-5.4/0.0/-23.7/0.0
germanrr	0/3/0	<b>3.1</b>	<b>11.2</b>	<b>77.0</b>	<b>11.1</b>	27.9/-27.7/-38.7/-55.9
gesa2	0/3/0	2.2	0.1	20.4	0.0	0.0/0.0/0.0/0.0
gesa2-o	0/3/0	<b>3.6</b>	0.1	31.0	<b>1.0</b>	47.1/0.0/2.2/23.1
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.4	1.0	0.0	0.0/0.0/0.0/0.0
glass4	3/0/0	287.8	0.1	89.3	36.9	-5.7/0.0/1.9/7.3
gmu-35-40	3/0/0	<b>9.7</b>	0.1	43.8	<b>5.7</b>	19.8/0.0/-4.1/-26.3
gmu-35-50	3/0/0	<b>6.2</b>	<b>0.2</b>	<b>50.4</b>	<b>6.3</b>	56.9/-50.0/-21.4/-38.1
graph20-20-1rand	3/0/0	<b>16.1</b>	<b>2.4</b>	<b>33.0</b>	<b>0.3</b>	53.5/14.3/-22.4/-100.0
graphdraw-domain	0/3/0	<b>52.5</b>	0.1	79.3	17.5	-30.5/0.0/-5.9/-1.1
h80x6320d	3/0/0	30.3	0.9	33.3	2.2	0.0/0.0/0.0/0.0
harp2	3/0/0	12.4	0.1	13.0	0.0	-5.6/0.0/6.5/0.0
highschool1-aigio	0/0/0	-	-	-	-	-/-/-/-
hypothyroid-k1	2/1/0	<b>35.9</b>	26.1	78.3	<b>22.4</b>	62.6/-6.9/-7.2/-35.3
ic97p	0/1/2	13.6	<b>2.9</b>	532.1	227.1	6.2/29.3/28.4/-24.8
ic97t	0/0/3	11.0	3.8	1043.9	375.4	-/-/-/-
icir97p	0/0/3	13.6	<b>46.2</b>	1264.3	425.4	2.9/-25.8/-28.8/-61.6
icir97t	0/1/2	<b>9.4</b>	<b>14.0</b>	488.9	291.7	29.9/44.9/30.3/38.2
irish-electricity	3/0/0	<b>4.5</b>	<b>65.2</b>	<b>49.4</b>	<b>3.2</b>	21.1/-13.2/-28.1/-43.8
irp	3/0/0	5.3	<b>0.7</b>	<b>16.3</b>	<b>0.0</b>	8.6/22.2/21.3/100.0
istanbul-no-cutoff	3/0/0	<b>3.5</b>	<b>6.6</b>	<b>10.0</b>	0.0	-48.6/18.5/-30.0/0.0
k1mushroom	3/0/0	18.2	84.2	1.0	0.0	0.0/0.1/0.0/0.0
lectsched-5-obj	0/0/2	2428.6	204.0	1412.2	1.4	-/-/-/-
leo1	3/0/0	842.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.32 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
leo2	3/0/0	7522.4	0.4	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>227.8</b>	0.6	90.0	<b>19.9</b>	66.2/0.0/2.9/44.6
lotsize	3/0/0	63.0	<i>0.4</i>	47.3	9.9	0.2/-25.0/0.6/2.0
mad	3/0/0	7882.7	0.1	12.3	0.0	0.9/0.0/-2.4/0.0
manna81	0/3/0	1.2	0.2	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<i>43.5</i>	<i>60.4</i>	<i>65.3</i>	<i>17.0</i>	-43.0/-11.4/-34.5/-65.3
map16715-04	3/0/0	<b>68.0</b>	<i>83.5</i>	<i>61.9</i>	<i>15.0</i>	27.1/-20.4/-33.3/-63.3
markshare1	3/0/0	44679.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	58088.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	6400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	3/0/0	80.0	0.1	89.0	<b>9.0</b>	-7.2/0.0/0.0/42.7
mas76	2/1/0	<b>17.3</b>	0.1	89.3	<b>9.8</b>	50.3/0.0/0.8/49.5
mc11	3/0/0	103.4	0.3	42.3	12.3	4.4/0.0/0.0/0.0
mcsched	3/0/0	<i>23.2</i>	<b>0.3</b>	3.6	0.0	-28.0/25.0/0.0/0.0
mik-250-20-75-4	0/3/0	<i>89.9</i>	0.1	<b>15.1</b>	<b>0.9</b>	-32.0/0.0/60.6/80.0
milo-v12-6-r2-40-1	0/0/3	103.3	<i>27.4</i>	1025.4	0.0	-8.9/-12.4/-13.3/0.0
misc07	3/0/0	69.5	0.1	<b>20.0</b>	<b>0.0</b>	1.3/0.0/31.3/100.0
mkc	3/0/0	26462.1	0.2	12.0	0.0	-1.9/0.0/0.0/0.0
mod011	3/0/0	<i>12.9</i>	0.2	21.7	<i>0.3</i>	-20.2/0.0/-6.9/-100.0
modglob	3/0/0	<i>5.6</i>	0.1	31.3	1.3	-94.6/0.0/0.0/0.0
momentum1	0/0/3	<i>323.3</i>	<i>27.5</i>	798.2	474.1	-28.0/-56.0/-60.9/-58.1
msc98-ip	3/0/0	<b>16.3</b>	<b>7.4</b>	26.8	0.3	24.9/16.9/-2.2/0.0
mushroom-best	0/3/0	1.25e07	120.2	<i>55.6</i>	3.9	1.6/-7.7/-11.9/-7.7
mzzv11	0/3/0	58.5	21.1	<i>23.6</i>	0.0	0.0/-0.9/-18.6/0.0
mzzv42z	0/3/0	62.9	8.8	<i>27.6</i>	<i>0.3</i>	-0.3/-4.5/-26.4/-100.0
n2seq36q	3/0/0	99.3	0.7	3.0	0.0	0.0/0.0/0.0/0.0
n3div36	3/0/0	99.3	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<i>47.5</i>	<i>0.5</i>	<i>20.4</i>	0.0	-22.1/-20.0/-31.9/0.0
neos-1122047	3/0/0	1.5	<i>1.5</i>	4.2	0.0	0.0/-13.3/0.0/0.0
neos-1171448	3/0/0	<b>2.6</b>	1.8	31.0	1.0	10.3/-5.6/0.0/0.0
neos-1171737	3/0/0	<b>6.8</b>	<i>0.7</i>	34.0	<i>3.0</i>	11.7/-14.3/-7.9/-56.7
neos-1354092	0/3/0	<i>8.4</i>	<b>167.0</b>	<i>46.9</i>	<i>0.4</i>	-29.8/28.0/-33.5/-100.0
neos-1445765	3/0/0	32.1	<i>61.9</i>	<i>12.3</i>	0.0	8.8/-29.9/-10.6/0.0
neos-1456979	0/0/3	<b>93.7</b>	<i>33.4</i>	950.4	105.0	22.6/-71.0/-80.1/-71.8
neos-1582420	0/3/0	<b>66.9</b>	<b>2.1</b>	<i>194.5</i>	<i>25.4</i>	28.4/12.5/-20.3/-44.1
neos-2657525-crna	0/2/1	856.3	<i>1.5</i>	470.3	29.8	-0.6/-40.0/-40.8/-73.8
neos-2746589-doon	0/3/0	<b>1033.1</b>	<b>102.9</b>	<b>198.8</b>	<b>19.1</b>	35.8/72.9/40.7/36.3
neos-2978193-inde	3/0/0	<b>10.4</b>	0.1	<i>2.6</i>	0.0	32.0/0.0/-11.5/0.0
neos-2987310-joes	0/0/0	0.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-3004026-krka	0/0/0	-	-	-	-	-/-/-/-
neos-3024952-loue	0/0/0	-	-	-	-	-/-/-/-
neos-3046615-murg	0/3/0	<i>1497.9</i>	0.1	90.7	<b>59.7</b>	-89.3/0.0/8.1/17.1
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/0	-	-	-	-	-/-/-/-
neos-3381206-awhea	0/0/3	4.9	25.7	979.2	0.3	-/-/-/-
neos-3402294-bobin	3/0/0	<b>455.2</b>	<b>7.0</b>	<b>16.7</b>	0.0	17.5/51.0/13.0/0.0
neos-3555904-turama	0/0/0	-	-	-	-	-/-/-/-
neos-3627168-kasai	3/0/0	1.4	<b>0.1</b>	<b>22.0</b>	<b>0.3</b>	0.0/50.0/24.7/50.0
neos-3656078-kumeu	0/2/1	736.6	<b>154.6</b>	508.9	106.4	-8.0/85.3/41.4/-67.4
neos-3754480-nidda	3/0/0	<b>9.3</b>	0.1	68.0	<b>10.9</b>	57.9/0.0/1.0/25.9
neos-4300652-rahue	0/2/1	168.7	1028.1	183.2	1.4	-/-/-/-
neos-4338804-snowy	0/3/0	<i>14031.6</i>	<b>0.4</b>	<b>121.3</b>	<b>34.1</b>	-25.4/55.6/37.9/23.2
neos-4387871-tavua	0/2/0	986.1	5.2	581.3	319.8	-/-/-/-
neos-4413714-turia	3/0/0	<b>70.3</b>	<b>45.4</b>	86.9	13.6	98.5/63.0/61.9/69.0
neos-4532248-waihi	0/0/3	949.4	<i>641.3</i>	1018.0	132.7	0.0/-39.0/-55.0/-68.6
neos-4647030-tutaki	3/0/0	53.0	<i>16.5</i>	<i>26.0</i>	0.0	-3.4/-11.5/-21.5/0.0
neos-4722843-widden	0/3/0	<b>22.5</b>	<b>13.2</b>	<b>49.7</b>	<b>7.9</b>	93.1/91.9/78.0/44.8
neos-4738912-atrato	0/3/0	<b>5.9</b>	0.3	11.5	0.0	47.8/0.0/7.3/0.0
neos-4763324-toguru	3/0/0	<i>34.9</i>	23.4	22.0	0.0	-12.0/-0.9/-3.2/0.0
neos-4954672-berkel	3/0/0	<b>26.8</b>	0.1	33.6	<i>1.9</i>	45.1/0.0/-3.9/-15.8
neos-5049753-cuanza	0/0/0	-	-	-	-	-/-/-/-

(continued)

Table A.32 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-5052403-cygnut	1/0/0	1.1	1967.4	3.0	0.0	-/-/-/
neos-5093327-huahum	3/0/0	<b>35.6</b>	<b>4.0</b>	<b>49.0</b>	<b>10.2</b>	25.1/42.9/24.3/30.1
neos-5104907-jarama	0/0/0	-	-	-	-	-/-/-/
neos-5107597-kakapo	3/0/0	<b>31538.8</b>	<b>1.4</b>	<b>111.3</b>	<b>78.6</b>	27.3/33.3/24.3/34.0
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/
neos-5188808-nattai	3/0/0	<b>333.8</b>	2.6	26.3	0.0	22.9/-3.8/0.0/0.0
neos-5195221-niemur	3/0/0	<b>276.2</b>	3.4	6.7	0.0	-14.7/2.9/4.3/0.0
neos-631710	3/0/0	162.4	1000.4	1.0	0.0	0.0/0.3/0.0/0.0
neos-662469	0/3/0	<b>1267.6</b>	4.9	4.0	0.0	-10.5/0.0/0.0/0.0
neos-787933	3/0/0	166.7	5.5	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	7.1	1.3	1.0	0.0	0.0/0.0/0.0/0.0
neos-848589	3/0/0	<b>4.31e05</b>	47.9	71.3	19.9	-22.7/-3.3/-2.8/6.6
neos-860300	3/0/0	46.3	<b>0.5</b>	<b>13.3</b>	0.0	-2.6/-20.0/-32.3/0.0
neos-873061	3/0/0	55.1	565.3	31.3	1.3	-8.9/-9.6/0.0/0.0
neos-911970	0/3/0	<b>210.2</b>	0.1	55.3	3.7	-14.9/0.0/-7.8/2.6
neos-933966	0/3/0	<b>151.3</b>	13.6	12.6	0.0	-23.1/0.0/-7.1/0.0
neos-950242	3/0/0	<b>52.2</b>	<b>15.6</b>	17.6	0.0	65.7/38.6/5.4/0.0
neos-957323	3/0/0	5.2	11.5	1.0	0.0	0.0/-0.9/0.0/0.0
neos-960392	2/1/0	<b>1.3</b>	<b>23.2</b>	<b>34.6</b>	<b>0.3</b>	13.3/-19.4/-51.4/-100.0
neos10	0/3/0	74.7	0.1	2.0	0.0	0.0/0.0/0.0/0.0
neos16	0/0/3	1.6	10.8	1220.4	48.3	-/-/-/
neos17	3/0/0	262.0	0.1	32.0	1.6	1.4/0.0/-0.9/0.0
neos20	0/0/3	38.2	<b>6.7</b>	1292.0	49.6	0.0/-14.9/-8.6/31.3
neos5	3/0/0	<b>30.6</b>	0.1	<b>3.3</b>	0.0	-28.1/0.0/17.5/0.0
neos7	0/3/0	<b>20.1</b>	<b>0.6</b>	<b>75.2</b>	<b>14.7</b>	72.6/-50.0/-27.1/-33.3
neos8	0/3/0	100.0	0.1	3.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	<b>41.2</b>	4.2	<b>36.0</b>	<b>1.2</b>	-41.3/-7.1/-36.4/-100.0
netdiversion	3/0/0	95.1	70.0	12.8	0.0	5.7/2.6/2.3/0.0
nexp-150-20-8-5	3/0/0	<b>148.0</b>	<b>1.6</b>	<b>31.3</b>	<b>1.0</b>	15.8/-18.8/-13.1/-40.0
nh97p	0/0/2	8.8	14.2	836.5	266.5	-/-/-/
nh97t	0/0/2	10.0	23.9	1250.0	318.8	-/-/-/
noswot	0/3/0	<b>7.1</b>	0.1	41.7	<b>3.3</b>	65.5/0.0/-8.9/-45.5
ns1116954	1/2/0	0.0	754.7	236.9	19.5	-/-/-/
ns1208400	0/1/1	9.0	361.4	960.5	1.6	-/-/-/
ns1644855	0/3/0	<b>16.7</b>	1468.4	<b>64.9</b>	<b>14.0</b>	-67.1/-7.9/-26.5/-54.3
ns1760995	3/0/0	<b>70.1</b>	<b>244.4</b>	<b>96.4</b>	<b>7.9</b>	-80.5/38.6/-18.8/-67.1
ns1830653	0/0/3	496.3	<b>21.6</b>	852.7	86.4	-4.5/-62.0/-68.8/-86.3
ns1952667	0/0/0	-	-	-	-	-/-/-/
nsrand-ixp	3/0/0	99.1	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	79.5	0.2	18.0	0.0	0.0/0.0/0.0/0.0
nursesched-medium-hint03	0/3/0	686.7	47.5	<b>17.6</b>	0.0	-9.2/-1.9/-23.3/0.0
nursesched-sprint02	0/3/0	40.2	2.3	<b>12.3</b>	0.0	-1.2/0.0/-22.0/0.0
nw04	3/0/0	<b>41.9</b>	<b>1.9</b>	<b>14.9</b>	0.0	-48.7/24.0/17.7/0.0
opm2-z10-s4	3/0/0	94.2	92.4	1.0	0.0	0.0/-1.4/0.0/0.0
opt1217	0/3/0	0.0	0.1	45.6	<b>6.0</b>	0.0/0.0/-8.3/-26.7
p200x1188c	3/0/0	<b>4.4</b>	0.1	31.0	1.0	-11.4/0.0/0.0/0.0
p2756	3/0/0	121.7	0.1	4.0	0.0	0.0/0.0/0.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/
pg	3/0/0	<b>3.6</b>	<b>0.2</b>	51.7	<b>15.0</b>	71.4/33.3/0.6/21.1
pg5-34	3/0/0	<b>3.4</b>	0.4	52.0	12.0	54.1/0.0/-2.7/0.8
physiciansched3-3	0/0/1	1044.3	2670.3	902.0	56.0	-/-/-/
physiciansched6-2	0/0/3	100.2	114.2	1023.6	0.6	-8.6/2.2/-11.1/0.0
piperout-08	0/0/3	<b>12.9</b>	<b>48.6</b>	1325.5	4.0	-16.3/-14.4/-8.3/27.3
piperout-27	0/0/3	<b>27.1</b>	<b>47.5</b>	865.2	2.6	58.2/16.4/16.3/36.6
pk1	3/0/0	<b>388.3</b>	0.1	<b>66.9</b>	<b>8.3</b>	75.5/0.0/-11.8/22.4
pp08a	3/0/0	<b>28.6</b>	0.1	<b>20.4</b>	0.0	48.7/0.0/-23.5/0.0
pp08aCUTS	3/0/0	<b>9.5</b>	0.1	<b>19.6</b>	0.0	63.0/0.0/-38.8/0.0
proteindesign121hz512p9	0/2/1	<b>17.2</b>	<b>111.0</b>	388.0	54.7	-68.6/20.4/8.9/-68.6
proteindesign122trx11p8	0/3/0	<b>2.0</b>	<b>26.2</b>	99.6	8.9	20.0/71.1/67.8/44.4
protfold	1/2/0	64.4	<b>161.2</b>	<b>161.0</b>	<b>4.3</b>	4.5/-69.0/-81.1/-93.0
qap10	3/0/0	41.5	<b>34.3</b>	3.0	0.0	0.0/-22.7/0.0/0.0

(continued)

Table A.32 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
qiu	3/0/0	921.9	0.1	<b>3.8</b>	<b>0.0</b>	-6.6/0.0/34.5/100.0
rB10-011000	3/0/0	262.4	0.6	26.2	<b>0.6</b>	-9.0/0.0/3.7/-50.0
rB10-011001	3/0/0	222.2	0.7	<b>23.2</b>	<b>0.0</b>	-6.8/0.0/15.9/100.0
rB11-010000	3/0/0	332.8	2.4	<b>26.8</b>	<b>0.3</b>	-7.5/0.0/13.3/50.0
rB11-110001	3/0/0	160.7	3.7	<b>34.6</b>	<b>0.8</b>	5.3/-5.4/-13.3/-62.5
rB12-111111	3/0/0	77.9	<b>7.2</b>	<b>167.1</b>	8.8	-1.7/32.1/32.3/-3.4
rC10-001000	3/0/0	<b>166.1</b>	0.2	26.0	0.0	36.4/0.0/1.1/0.0
rC10-100001	3/0/0	<b>358.5</b>	<b>2.0</b>	<b>93.2</b>	1.3	26.8/-15.0/-18.5/0.0
rC11-010100	0/3/0	333.8	2.1	2.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	0/3/0	480.5	0.8	2.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	<b>331.7</b>	8.1	<b>43.6</b>	<b>0.8</b>	31.6/-9.9/-30.7/27.3
rC12-111100	3/0/0	194.9	0.6	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>165.4</b>	<b>2.4</b>	<b>100.1</b>	<b>3.6</b>	-17.7/-29.2/-26.6/16.3
radiationm40-10-02	0/3/0	<b>138.2</b>	<b>31.7</b>	<b>294.8</b>	25.9	19.5/-36.9/-28.8/9.4
rail01	0/0/0	-	-	-	-	-/-/-/-
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	25.1	4.6	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	16.1	0.2	20.4	<b>0.0</b>	0.0/0.0/7.3/100.0
rd-rplusc-21	0/0/3	102.3	<b>48.3</b>	814.0	317.1	-2.0/-12.6/1.9/13.4
reblock115	3/0/0	<b>8.2</b>	0.7	<b>40.2</b>	<b>2.3</b>	24.8/0.0/17.6/59.6
rmatr100-p10	3/0/0	<b>17.7</b>	1.4	2.3	0.0	40.0/6.7/0.0/0.0
rmatr200-p5	3/0/0	19.5	64.0	2.0	0.0	0.0/0.3/0.0/0.0
rocl-4-11	0/0/3	54.7	32.0	1025.8	3.3	-/-/-/-
rocll-5-11	0/0/3	81.6	34.9	1288.7	515.1	-/-/-/-
roi2alpha3n4	3/0/0	<b>42.4</b>	35.6	38.3	<b>2.4</b>	36.5/-7.0/-9.4/-16.7
roi5alpha10n8	3/0/0	58.0	<b>483.0</b>	<b>34.3</b>	<b>1.5</b>	-1.0/-11.0/-14.6/-100.0
roll3000	0/3/0	<b>41.6</b>	<b>2.2</b>	<b>194.7</b>	<b>39.0</b>	-12.7/-63.6/-67.8/-75.1
rout	0/3/0	14400.5	0.1	<b>42.9</b>	<b>3.9</b>	-9.1/0.0/-17.2/-56.4
s100	2/1/0	14.8	2875.9	7.8	0.0	-/-/-/-
s250r10	0/3/0	0.1	334.0	3.0	0.0	0.0/0.3/0.0/0.0
satellites2-40	0/0/0	-	-	-	-	-/-/-/-
satellites2-60-fs	0/0/0	-	-	-	-	-/-/-/-
savsched1	0/0/0	-	-	-	-	-/-/-/-
sct2	3/0/0	<b>25.5</b>	<b>0.3</b>	<b>31.1</b>	<b>0.8</b>	-64.7/-33.3/-33.8/-100.0
set1ch	3/0/0	61.7	0.1	31.0	1.0	-9.2/0.0/0.0/0.0
seymour	3/0/0	16.1	1.4	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	3.8	1.6	<b>9.3</b>	0.0	-7.9/0.0/-14.0/0.0
sing326	3/0/0	59.6	75.7	<b>23.5</b>	0.6	0.0/0.1/-11.1/0.0
sing44	3/0/0	21.2	74.4	12.4	0.0	-2.8/0.3/-2.4/0.0
snp-02-004-104	0/3/0	<b>7.2</b>	<b>209.0</b>	35.9	<b>2.9</b>	66.0/32.4/7.5/19.4
sorrell3	3/0/0	39.9	5.2	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	1.4	0.1	31.7	<b>1.6</b>	0.0/0.0/-1.3/-18.8
sp97ar	3/0/0	6449.4	2.7	2.2	0.0	1.0/3.6/8.3/0.0
sp98ar	3/0/0	698.4	1.5	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	98.2	138.3	<b>15.0</b>	0.0	1.2/8.2/-15.3/0.0
square41	0/0/0	-	-	-	-	-/-/-/-
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	113.7	470.2	11.3	0.0	7.2/-1.5/-3.5/0.0
supportcase12	0/3/0	<b>1.7</b>	199.8	21.3	0.0	-17.6/2.8/-1.4/0.0
supportcase18	3/0/0	41.7	1.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>383.7</b>	0.1	89.3	59.3	-15.7/0.0/0.0/5.4
supportcase33	0/3/0	95.4	<b>4.6</b>	<b>164.0</b>	<b>33.7</b>	-2.0/-21.7/-34.2/-43.3
supportcase40	3/0/0	<b>14.6</b>	1.3	17.7	0.0	17.0/7.1/-6.2/0.0
supportcase42	0/3/0	2.91e06	14.3	16.2	0.0	0.0/1.4/4.1/0.0
supportcase6	3/0/0	<b>2.8</b>	<b>34.3</b>	<b>20.1</b>	0.0	-78.6/-28.3/-42.3/0.0
supportcase7	3/0/0	12.2	4.2	25.0	0.0	0.0/0.0/0.0/0.0
swath	0/3/0	190.9	<b>8.0</b>	<b>302.1</b>	<b>112.0</b>	2.7/-55.0/-44.3/-49.4
swath1	3/0/0	<b>8.4</b>	<b>0.5</b>	<b>47.6</b>	<b>5.4</b>	44.0/-20.0/-33.6/-61.1
swath3	3/0/0	<b>22.1</b>	<b>0.7</b>	<b>67.9</b>	<b>17.6</b>	-38.9/-14.3/-20.6/-31.3
t1717	2/0/0	141.5	387.1	52.7	0.0	-/-/-/-
tbfp-network	3/0/0	<b>27.1</b>	40.9	<b>12.6</b>	0.0	64.1/0.0/-11.9/0.0

(continued)

Table A.32 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
thor50dday	3/0/0	257.8	161.5	24.5	1.7	0.0/-0.2/0.0/0.0
timtab1	0/2/1	<b>56.5</b>	<i>1.9</i>	320.7	139.2	13.2/-57.9/-44.0/-46.0
timtab2	0/3/0	<b>50.3</b>	<b>2.7</b>	305.1	126.7	31.1/65.8/63.0/58.7
tr12-30	3/0/0	<b>50.9</b>	0.1	<i>35.3</i>	<i>3.2</i>	29.8/0.0/-10.2/-50.0
traininstance2	0/1/2	<b>64.8</b>	<b>18.8</b>	847.6	55.8	34.9/38.2/45.3/-31.5
traininstance6	0/1/2	<i>817.4</i>	<i>11.2</i>	1158.3	79.9	-61.9/-43.8/-38.7/19.0
trento1	0/3/0	<i>126.7</i>	<i>51.3</i>	10.3	0.0	-15.3/-35.7/0.0/0.0
triptim1	0/3/0	0.0	81.2	<i>8.3</i>	0.0	0.0/-5.2/-33.7/0.0
uccase12	3/0/0	<b>286.0</b>	261.7	<i>19.7</i>	0.0	16.5/-0.1/-15.2/0.0
uccase9	3/0/0	<i>219.5</i>	57.9	<i>87.0</i>	27.8	-17.7/-5.4/-11.6/-5.0
uct-subprob	3/0/0	22.5	<b>0.6</b>	<i>13.0</i>	0.0	-0.9/14.3/-21.5/0.0
unitcal-7	0/0/2	22.0	81.7	809.8	93.7	-/-/-/-
var-smallemerly-m6j6	3/0/0	<b>21.1</b>	19.3	<i>73.3</i>	<i>11.6</i>	58.1/-8.8/-10.6/-20.7
vpm2	3/0/0	479.5	0.1	<i>27.2</i>	<i>0.3</i>	-2.0/0.0/-25.0/-100.0
wachplan	0/3/0	0.0	<i>2.0</i>	<i>39.7</i>	<b>0.0</b>	0.0/-20.0/-24.2/100.0
Geom. means		(239 instances)	(208 instances)			
FP		63.5	5.7	16.8	1.3	
FP+(3,sv,g)		<b>59.1</b>	<b>5.6</b>	<i>18.0</i>	<i>1.4</i>	

Table A.33.: Performance of FP+(3,sv,g,c,Δ) with SCIP

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
10teams	0/2/1	<b>3.4</b>	<i>10.0</i>	336.3	28.1	34.6/-55.0/-77.3/-96.1
30n20b8	0/0/3	<b>176.8</b>	<i>39.3</i>	1303.9	276.6	35.5/-13.5/-11.6/-32.1
50v-10	0/3/0	125.9	0.3	<b>22.0</b>	0.3	-9.1/0.0/19.1/0.0
CMS750-4	3/0/0	<i>72.7</i>	<i>3.0</i>	89.4	<i>18.7</i>	-17.2/-13.3/-9.2/-12.3
a1c1s1	3/0/0	<b>23.9</b>	<i>0.3</i>	32.0	<i>1.9</i>	23.2/-33.3/-0.9/-31.6
academictimetables-small	0/0/0	-	-	-	-	-/-/-/-
aflow30a	3/0/0	163.9	0.1	<i>54.1</i>	<i>8.4</i>	-5.8/0.0/-18.7/-28.6
aflow40b	3/0/0	102.2	0.3	34.4	2.5	-1.8/0.0/2.0/3.8
air04	3/0/0	<i>0.9</i>	<i>7.7</i>	<i>23.4</i>	0.0	-44.4/-48.1/-63.7/0.0
air05	3/0/0	<i>7.1</i>	<i>1.9</i>	<i>15.8</i>	0.0	-49.3/-15.8/-61.4/0.0
app1-1	3/0/0	<i>53.0</i>	0.1	35.5	<i>4.5</i>	-70.6/0.0/-6.2/-35.6
app1-2	3/0/0	41.5	2.7	40.9	9.3	3.7/0.0/1.7/7.0
arki001	0/1/1	2.5	24.0	598.4	173.9	-/-/-/-
assign1-5-8	0/3/0	<i>5.4</i>	0.1	<b>6.0</b>	0.0	-64.8/0.0/75.5/0.0
atlanta-ip	2/1/0	<b>17.6</b>	<b>25.2</b>	<b>26.1</b>	<b>1.4</b>	55.4/21.7/49.2/39.1
b1c1s1	3/0/0	<b>93.3</b>	<i>0.2</i>	34.3	<i>3.9</i>	35.9/-50.0/-2.9/-23.1
bab2	0/0/3	23.4	<i>938.6</i>	899.2	215.0	5.6/-65.5/-89.8/-93.2
bab6	0/0/3	<i>33.9</i>	<i>552.4</i>	778.7	244.6	-54.6/-71.3/-92.1/-98.2
beasleyC3	3/0/0	11.1	0.1	35.7	<i>5.6</i>	9.8/0.0/-2.0/-14.3
binkar10-1	3/0/0	<b>1.7</b>	0.1	6.0	0.0	59.5/0.0/7.7/0.0
blp-ar98	3/0/0	<b>75.5</b>	<b>1.3</b>	<b>15.5</b>	<b>0.0</b>	13.9/18.8/26.5/100.0
blp-ic98	3/0/0	51.9	0.2	1.0	0.0	0.0/0.0/0.0/0.0
bnatt400	0/0/1	0.0	94.2	1244.0	0.0	-/-/-/-
bppc4-08	0/3/0	35.1	<b>0.2</b>	<b>7.0</b>	<b>0.0</b>	9.3/60.0/88.2/100.0
brazil3	0/3/0	<i>863.1</i>	<i>84.0</i>	<i>57.9</i>	0.0	-23.5/-43.3/-44.2/0.0
buildingenergy	0/3/0	1.6	1178.3	4.0	0.0	-/-/-/-
cap6000	3/0/0	0.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
cbs-cta	3/0/0	<b>0.0</b>	<b>2.2</b>	32.0	<i>1.3</i>	100.0/-4.5/-3.1/-23.1
chromaticindex1024-7	3/0/0	0.0	<i>3120.7</i>	<i>7.6</i>	0.0	0.0/-77.2/-73.7/0.0
chromaticindex512-7	3/0/0	0.0	158.2	<i>2.0</i>	0.0	0.0/-9.9/-35.0/0.0
cmflsp50-24-8-8	3/0/0	14.5	12.3	158.2	40.9	-/-/-/-
co-100	3/0/0	<i>59179.0</i>	2.4	13.3	0.0	-24.7/-4.2/-5.3/0.0
cod105	3/0/0	100.0	15.5	1.0	0.0	0.0/0.0/0.0/0.0
comp07-2idx	0/3/0	<i>4554.4</i>	<i>31.2</i>	<i>55.9</i>	<i>0.6</i>	-24.3/-52.9/-61.9/-100.0
comp21-2idx	0/3/0	<i>1023.7</i>	<i>9.9</i>	<i>65.8</i>	<i>1.3</i>	-52.4/-14.1/-62.3/-100.0

(continued)

Table A.33 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
cost266-UUE	0/0/3	<b>105.8</b>	0.2	6.0	0.0	-28.2/0.0/46.9/0.0
cryptanalysisiskb128n5obj16	0/0/0	-	-	-	-	-/-/-/-
csched007	0/2/1	<b>65.6</b>	<b>37.5</b>	420.6	16.9	12.6/74.2/30.7/32.1
csched008	0/3/0	9.8	<b>2.3</b>	<b>81.9</b>	<b>8.9</b>	-6.1/68.1/43.7/51.1
cvs16r128-89	3/0/0	97.9	3.3	1.0	0.0	0.0/0.0/0.0/0.0
dano3-3	3/0/0	0.0	64.3	<b>2.0</b>	0.0	0.0/-5.1/87.7/0.0
dano3-5	3/0/0	<b>0.3</b>	<b>97.3</b>	<b>2.0</b>	<b>0.0</b>	-66.7/17.2/93.2/100.0
dano3mip	3/0/0	<b>15.4</b>	<b>140.3</b>	<b>5.0</b>	<b>0.0</b>	36.4/68.0/93.0/100.0
danooint	2/1/0	24.3	<b>1.2</b>	<b>98.2</b>	<b>22.4</b>	0.4/70.0/23.5/52.0
disctom	3/0/0	0.0	6.2	2.0	0.0	0.0/0.0/0.0/0.0
drayage-100-23	3/0/0	<b>167.9</b>	<b>1.4</b>	<b>43.7</b>	<b>1.3</b>	-14.2/-21.4/-24.0/-69.2
drayage-25-23	3/0/0	167.3	<b>2.1</b>	<b>69.5</b>	1.3	2.2/-28.6/-41.2/0.0
ds	0/0/0	-	-	-	-	-/-/-/-
dws008-01	0/0/0	-	-	-	-	-/-/-/-
eil33-2	0/3/0	<b>31.2</b>	<b>4.5</b>	<b>223.2</b>	<b>48.8</b>	41.0/-86.7/-86.2/-99.2
eilA101-2	0/1/2	<b>251.6</b>	1041.0	614.8	32.3	-32.6/2.6/-9.8/-75.2
enlight-hard	0/0/0	-	-	-	-	-/-/-/-
exp-1-500-5-5	3/0/0	<b>168.3</b>	0.1	<b>23.4</b>	0.0	-58.2/0.0/13.0/0.0
fast0507	3/0/0	24.2	4.6	1.0	0.0	0.0/0.0/0.0/0.0
fastxgemm-n2r6s0t2	0/1/2	2714.2	18.3	731.9	165.6	0.0/5.7/4.3/-8.0
fhnw-binpack4-48	0/0/0	-	-	-	-	-/-/-/-
fiball	0/3/0	<b>10.5</b>	<b>9.2</b>	79.7	<b>7.4</b>	-12.4/-17.4/-7.0/-28.4
fiber	3/0/0	27192.6	0.1	1.0	0.0	0.0/0.0/0.0/0.0
fixnet6	3/0/0	<b>34.0</b>	0.1	31.0	1.0	-18.5/0.0/0.0/0.0
gen-ip002	0/3/0	13.9	0.1	1.0	0.0	0.0/0.0/0.0/0.0
gen-ip054	0/3/0	<b>12.7</b>	0.1	3.1	0.0	-17.3/0.0/-6.5/0.0
germanrr	0/3/0	<b>3.0</b>	<b>5.7</b>	<b>36.2</b>	<b>2.1</b>	30.2/29.6/23.3/57.1
gesa2	0/3/0	2.4	0.1	20.4	0.0	-8.3/0.0/0.0/0.0
gesa2-o	0/3/0	<b>8.4</b>	0.1	31.0	<b>1.0</b>	-19.0/0.0/2.2/23.1
gfd-schedulen180f7d50m30k18	0/0/0	-	-	-	-	-/-/-/-
glass-sc	3/0/0	13.4	0.4	1.0	0.0	0.0/0.0/0.0/0.0
glass4	3/0/0	<b>207.6</b>	0.1	<b>11.0</b>	<b>0.0</b>	23.5/0.0/87.9/100.0
gmu-35-40	3/0/0	<b>7.4</b>	0.1	<b>3.0</b>	<b>0.0</b>	38.8/0.0/92.9/100.0
gmu-35-50	3/0/0	<b>5.7</b>	0.1	<b>32.6</b>	<b>1.0</b>	60.4/0.0/17.7/74.4
graph20-20-1rand	3/0/0	<b>17.7</b>	<b>1.8</b>	24.9	<b>0.3</b>	48.8/35.7/2.7/-100.0
graphdraw-domain	0/3/0	<b>44.5</b>	0.1	<b>34.9</b>	<b>2.1</b>	-18.0/0.0/53.2/87.9
h80x6320d	3/0/0	<b>34.0</b>	0.9	33.3	2.2	-10.9/0.0/0.0/0.0
harp2	3/0/0	12.0	0.1	12.6	0.0	-2.5/0.0/9.4/0.0
highschool1-aigio	0/0/0	-	-	-	-	-/-/-/-
hypothyroid-k1	2/1/0	<b>32.7</b>	24.9	79.8	<b>23.0</b>	66.0/-2.4/-8.9/-37.0
ic97p	0/3/0	<b>11.1</b>	<b>1.7</b>	406.1	159.4	23.4/58.5/45.4/6.7
ic97t	0/0/3	9.3	2.8	936.4	369.4	-/-/-/-
icir97p	0/0/3	14.6	<b>30.4</b>	1108.5	329.6	-4.1/11.4/-18.8/-50.5
icir97t	0/1/2	<b>9.9</b>	<b>13.3</b>	565.6	331.1	26.1/47.6/19.4/29.8
irish-electricity	3/0/0	<b>13.0</b>	53.8	34.5	<b>2.3</b>	-56.2/4.9/2.8/-21.7
irp	3/0/0	5.3	<b>0.8</b>	<b>16.3</b>	<b>0.0</b>	8.6/11.1/21.3/100.0
istanbul-no-cutoff	3/0/0	<b>13.0</b>	7.9	<b>12.3</b>	0.0	-86.2/2.5/-43.1/0.0
k1mushroom	3/0/0	18.2	83.0	1.0	0.0	0.0/1.5/0.0/0.0
lectsched-5-obj	0/0/1	2591.7	234.0	1992.0	31.0	-/-/-/-
leo1	3/0/0	842.0	0.2	1.0	0.0	0.0/0.0/0.0/0.0
leo2	3/0/0	7522.4	0.4	1.0	0.0	0.0/0.0/0.0/0.0
liu	3/0/0	<b>295.9</b>	<b>0.1</b>	<b>13.0</b>	<b>0.0</b>	56.1/83.3/86.0/100.0
lotsize	3/0/0	<b>185.1</b>	0.3	<b>42.7</b>	<b>8.0</b>	-65.9/0.0/10.3/20.8
mad	3/0/0	7884.0	0.1	<b>16.3</b>	0.0	0.8/0.0/-26.4/0.0
manna81	0/3/0	1.2	0.2	2.6	0.0	0.0/0.0/0.0/0.0
map10	3/0/0	<b>63.5</b>	<b>26.1</b>	<b>7.7</b>	<b>0.0</b>	-60.9/51.2/82.0/100.0
map16715-04	3/0/0	<b>70.4</b>	<b>28.4</b>	<b>8.3</b>	<b>0.0</b>	24.5/57.3/79.9/100.0
markshare1	3/0/0	44679.3	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare2	3/0/0	58088.2	0.1	1.0	0.0	0.0/0.0/0.0/0.0
markshare-4-0	3/0/0	6400.0	0.1	1.0	0.0	0.0/0.0/0.0/0.0
mas74	3/0/0	<b>44.2</b>	0.1	<b>7.6</b>	<b>0.0</b>	40.4/0.0/91.5/100.0

(continued)



Table A.33 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
mas76	3/0/0	<b>12.2</b>	0.1	<b>3.9</b>	<b>0.0</b>	64.9/0.0/95.7/100.0
mc11	3/0/0	114.9	0.3	43.3	13.3	-5.8/0.0/-2.3/-7.5
mcsched	3/0/0	<b>57.5</b>	<b>0.3</b>	3.6	0.0	-71.0/25.0/0.0/0.0
mik-250-20-75-4	0/3/0	<b>28.0</b>	0.1	<b>6.9</b>	<b>0.0</b>	54.2/0.0/82.0/100.0
milo-v12-6-r2-40-1	0/0/3	97.2	25.0	959.5	0.0	-3.2/-4.0/-7.3/0.0
misc07	3/0/0	70.0	0.1	<b>22.9</b>	<b>0.0</b>	0.6/0.0/21.3/100.0
mkc	3/0/0	26698.7	<b>0.1</b>	<b>6.0</b>	0.0	-2.8/50.0/50.0/0.0
mod011	3/0/0	<b>6.0</b>	<b>0.1</b>	<b>6.7</b>	0.0	41.7/50.0/66.8/0.0
modglob	3/0/0	<b>50.8</b>	0.1	<b>6.0</b>	<b>0.0</b>	-99.4/0.0/80.8/100.0
momentum1	0/0/3	<b>323.3</b>	<b>40.1</b>	1468.6	1007.4	-28.0/-69.8/-78.7/-80.3
msc98-ip	3/0/0	<b>16.5</b>	<b>6.4</b>	<b>19.6</b>	0.3	24.0/28.1/25.2/0.0
mushroom-best	0/3/0	1.24e07	<b>897.7</b>	<b>107.9</b>	<b>32.0</b>	2.4/-87.6/-54.6/-88.8
mzzv11	0/3/0	63.4	<b>26.5</b>	<b>53.2</b>	<b>9.9</b>	-7.7/-21.1/-63.9/-100.0
mzzv42z	0/3/0	62.6	<b>7.4</b>	<b>11.7</b>	0.0	0.2/11.9/42.4/0.0
n2seq36q	3/0/0	99.4	<b>0.8</b>	3.0	0.0	-0.1/-12.5/0.0/0.0
n3div36	3/0/0	99.3	0.4	1.0	0.0	0.0/0.0/0.0/0.0
n5-3	0/3/0	<b>33.2</b>	<b>0.5</b>	<b>20.4</b>	0.0	10.3/-20.0/-31.9/0.0
neos-1122047	3/0/0	1.5	1.4	<b>2.6</b>	0.0	0.0/-7.1/38.1/0.0
neos-1171448	3/0/0	<b>6.9</b>	<b>0.6</b>	<b>3.9</b>	<b>0.0</b>	-58.0/64.7/87.4/100.0
neos-1171737	3/0/0	<b>12.9</b>	<b>0.2</b>	<b>4.2</b>	<b>0.0</b>	-40.3/66.7/86.6/100.0
neos-1354092	0/3/0	<b>7.0</b>	<b>106.4</b>	<b>27.7</b>	0.0	-15.7/54.1/11.2/0.0
neos-1445765	3/0/0	<b>44.3</b>	<b>32.9</b>	<b>8.3</b>	0.0	-20.5/24.2/24.5/0.0
neos-1456979	0/1/2	<b>105.7</b>	<b>19.0</b>	516.8	40.5	12.6/-48.9/-63.5/-26.9
neos-1582420	0/3/0	<b>54.0</b>	<b>0.8</b>	<b>76.8</b>	<b>10.3</b>	42.2/66.7/50.5/27.5
neos-2657525-crna	0/3/0	874.9	<b>0.2</b>	77.5	1.9	-2.7/77.8/72.2/75.6
neos-2746589-doon	0/3/0	<b>1091.6</b>	<b>205.2</b>	<b>246.7</b>	<b>21.6</b>	32.1/45.9/26.4/28.0
neos-2978193-inde	3/0/0	<b>3.4</b>	0.1	<b>3.3</b>	0.0	77.8/0.0/-30.3/0.0
neos-2987310-joes	0/0/0	0.0	0.1	0.0	0.0	0.0/0.0/0.0/0.0
neos-3004026-krka	0/0/0	-	-	-	-	-/-/-/-
neos-3024952-loue	0/0/1	567.1	129.6	1456.0	0.0	-/-/-/-
neos-3046615-murg	0/3/0	<b>21.5</b>	0.1	<b>81.6</b>	<b>50.6</b>	86.6/0.0/17.3/29.7
neos-3083819-nubu	0/3/0	0.8	0.1	1.0	0.0	0.0/0.0/0.0/0.0
neos-3216931-puriri	0/0/1	54.1	800.2	844.0	3.0	-/-/-/-
neos-3381206-awhea	0/0/3	4.9	16.6	777.9	0.0	-/-/-/-
neos-3402294-bobin	3/0/0	<b>181.2</b>	<b>7.5</b>	<b>16.3</b>	0.0	67.2/47.6/15.1/0.0
neos-3555904-turama	0/0/0	-	-	-	-	-/-/-/-
neos-3627168-kasai	3/0/0	<b>1.2</b>	<b>0.1</b>	<b>22.0</b>	<b>0.3</b>	14.3/50.0/24.7/50.0
neos-3656078-kumeu	0/1/1	717.9	354.1	705.5	35.7	-/-/-/-
neos-3754480-nidda	3/0/0	<b>33.1</b>	0.1	<b>17.5</b>	<b>0.0</b>	-33.2/0.0/74.5/100.0
neos-4300652-rahue	0/2/1	167.9	1495.1	310.4	6.0	-/-/-/-
neos-4338804-snowy	0/3/0	<b>14481.3</b>	<b>0.3</b>	<b>91.4</b>	<b>23.7</b>	-27.8/66.7/53.2/46.6
neos-4387871-tavua	0/2/0	851.0	2.5	287.6	153.4	-/-/-/-
neos-4413714-turia	3/0/0	<b>797.3</b>	<b>14.4</b>	11.0	0.0	82.5/88.3/95.2/100.0
neos-4532248-waihi	0/0/3	949.4	<b>841.1</b>	1289.3	133.7	0.0/-53.5/-64.4/-68.8
neos-4647030-tutaki	3/0/0	<b>58.5</b>	15.1	22.3	0.0	-12.5/-3.3/-8.5/0.0
neos-4722843-widden	0/2/1	<b>28.0</b>	<b>69.0</b>	137.7	18.3	91.4/57.7/39.1/-21.9
neos-4738912-atrato	0/3/0	<b>6.6</b>	0.3	<b>8.9</b>	0.0	41.6/0.0/28.2/0.0
neos-4763324-toguru	3/0/0	<b>34.4</b>	21.8	<b>9.3</b>	0.0	-10.8/6.0/56.3/0.0
neos-4954672-berkel	3/0/0	<b>94.5</b>	0.1	<b>13.9</b>	<b>0.0</b>	-48.4/0.0/57.0/100.0
neos-5049753-cuanza	0/0/0	-	-	-	-	-/-/-/-
neos-5052403-cygnnet	1/0/0	0.5	1971.5	3.0	0.0	-/-/-/-
neos-5093327-huahum	3/0/0	<b>25.3</b>	<b>3.1</b>	<b>36.3</b>	<b>4.4</b>	46.7/55.7/43.9/69.9
neos-5104907-jarama	0/0/0	-	-	-	-	-/-/-/-
neos-5107597-kakapo	3/0/0	42214.0	<b>1.3</b>	<b>102.6</b>	<b>71.0</b>	2.7/38.1/30.2/40.4
neos-5114902-kasavu	0/0/0	-	-	-	-	-/-/-/-
neos-5188808-nattai	3/0/0	446.9	<b>1.9</b>	<b>17.0</b>	0.0	-3.1/24.0/35.4/0.0
neos-5195221-niemur	3/0/0	<b>398.5</b>	<b>6.4</b>	<b>4.8</b>	0.0	-40.9/-45.3/31.4/0.0
neos-631710	3/0/0	162.4	996.4	1.0	0.0	0.0/0.7/0.0/0.0
neos-662469	0/3/0	1232.5	4.9	4.0	0.0	-7.9/0.0/0.0/0.0
neos-787933	3/0/0	166.7	5.5	1.0	0.0	0.0/0.0/0.0/0.0
neos-827175	3/0/0	7.1	1.3	1.0	0.0	0.0/0.0/0.0/0.0

(continued)

Table A.33 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
neos-848589	3/0/0	3.65e05	54.7	78.3	23.3	-8.8/-15.4/-11.5/-8.6
neos-860300	3/0/0	40.9	0.4	8.0	0.0	9.3/0.0/11.1/0.0
neos-873061	3/0/0	54.8	449.2	31.3	1.3	-8.4/12.1/0.0/0.0
neos-911970	0/3/0	213.9	0.1	20.6	0.0	-16.4/0.0/59.6/100.0
neos-933966	0/3/0	3.2	18.1	7.6	0.0	97.2/-24.9/35.0/0.0
neos-950242	3/0/0	132.0	47.2	38.6	0.3	13.2/-46.2/-51.8/-100.0
neos-957323	3/0/0	5.2	11.4	1.0	0.0	0.0/0.0/0.0/0.0
neos-960392	3/0/0	2.2	19.4	33.2	0.0	-31.8/-3.6/-49.4/0.0
neos10	0/3/0	74.7	0.1	2.0	0.0	0.0/0.0/0.0/0.0
neos16	0/0/2	1.1	9.0	1319.6	16.5	-/-/-/-
neos17	3/0/0	253.5	0.1	34.9	2.7	4.6/0.0/-9.2/-40.7
neos20	0/0/3	38.2	8.1	1467.8	33.2	0.0/-29.6/-19.6/54.0
neos5	3/0/0	38.8	0.1	2.9	0.0	-43.3/0.0/27.5/0.0
neos7	0/3/0	11.3	0.1	7.9	0.0	84.6/66.7/85.6/100.0
neos8	0/3/0	100.0	0.1	3.6	0.0	0.0/0.0/0.0/0.0
net12	3/0/0	24.2	4.3	26.5	0.0	0.0/-9.3/-13.6/0.0
netdiversion	3/0/0	80.6	438.2	14.2	0.0	20.1/-83.6/-7.7/0.0
nexp-150-20-8-5	3/0/0	190.6	2.2	41.6	1.3	-7.8/-40.9/-34.6/-53.8
nh97p	0/0/1	12.4	19.4	1172.0	384.0	-/-/-/-
nh97t	0/0/2	11.0	16.4	1067.6	264.9	-/-/-/-
noswot	0/3/0	8.9	0.1	14.4	1.6	56.8/0.0/62.1/11.1
ns1116954	1/2/0	0.0	751.7	236.9	19.5	-/-/-/-
ns1208400	0/1/1	13.2	193.6	679.4	5.0	-/-/-/-
ns1644855	0/3/0	28.3	456.3	6.3	0.0	-80.6/66.2/86.8/100.0
ns1760995	3/0/0	23.1	117.5	23.6	0.0	-40.7/70.5/69.9/100.0
ns1830653	0/0/3	488.5	22.9	822.7	39.0	-3.0/-64.2/-67.6/-69.7
ns1952667	0/0/0	-	-	-	-	-/-/-/-
nsrand-ixp	3/0/0	99.1	0.1	1.0	0.0	0.0/0.0/0.0/0.0
nu25-pr12	0/3/0	79.6	0.1	3.0	0.0	-0.1/50.0/83.3/0.0
nursesched-medium-hint03	0/3/0	648.3	141.4	43.6	0.3	-3.8/-67.0/-69.0/-100.0
nursesched-sprint02	0/3/0	26.6	2.5	13.3	0.0	33.0/-8.0/-27.8/0.0
nw04	3/0/0	43.3	1.1	7.0	0.0	-50.3/56.0/61.3/0.0
opm2-z10-s4	3/0/0	94.2	92.6	1.0	0.0	0.0/-1.6/0.0/0.0
opt1217	0/3/0	0.0	0.1	5.6	0.0	0.0/0.0/86.6/100.0
p200x1188c	3/0/0	3.9	0.1	31.0	1.0	0.0/0.0/0.0/0.0
p2756	3/0/0	121.2	0.1	3.0	0.0	0.4/0.0/25.0/0.0
peg-solitaire-a3	0/0/0	-	-	-	-	-/-/-/-
pg	3/0/0	4.5	0.1	16.6	0.0	64.3/66.7/68.1/100.0
pg5-34	3/0/0	7.6	0.1	7.4	0.0	-2.6/75.0/85.4/100.0
physiciansched3-3	0/3/0	346.3	2219.6	326.9	9.6	-93.2/30.1/-74.2/-93.8
physiciansched6-2	0/0/3	103.4	145.5	1322.1	1.0	-11.4/-19.7/-31.2/-40.0
piperout-08	0/0/3	35.3	56.3	1543.5	2.3	-69.4/-26.1/-21.3/58.2
piperout-27	0/0/3	31.3	90.3	1372.0	2.3	51.8/-37.1/-24.7/43.9
pk1	3/0/0	192.0	0.1	31.2	0.3	87.9/0.0/47.1/97.2
pp08a	3/0/0	52.9	0.1	16.7	0.0	5.2/0.0/-6.6/0.0
pp08aCUTS	3/0/0	14.2	0.1	10.5	0.0	44.7/0.0/12.5/0.0
proteindesign121hz512p9	0/3/0	6.3	102.5	394.6	54.0	-14.3/26.5/7.3/-68.1
proteindesign122trx11p8	0/3/0	2.5	24.4	90.0	6.2	0.0/73.1/70.9/61.3
protfold	2/0/1	56.7	94.9	97.4	3.6	15.9/-47.4/-68.8/-91.7
qap10	3/0/0	40.3	39.9	6.0	0.0	2.9/-33.6/-50.0/0.0
qiu	3/0/0	1534.7	0.1	3.8	0.0	-43.9/0.0/34.5/100.0
rB10-011000	3/0/0	317.3	0.6	23.8	0.3	-24.8/0.0/12.5/0.0
rB10-011001	3/0/0	225.9	0.7	21.7	0.0	-8.4/0.0/21.4/100.0
rB11-010000	3/0/0	366.7	2.4	26.0	0.6	-16.1/0.0/15.9/0.0
rB11-110001	3/0/0	170.8	3.6	29.6	0.3	-0.6/-2.8/1.3/0.0
rB12-111111	2/1/0	75.2	6.1	119.7	5.6	1.8/42.5/51.5/34.1
rC10-001000	3/0/0	174.7	0.3	30.3	0.0	33.1/-33.3/-13.2/0.0
rC10-100001	3/0/0	415.9	2.5	123.3	0.6	15.1/-32.0/-38.4/53.8
rC11-010100	0/3/0	333.8	2.1	2.0	0.0	0.0/0.0/0.0/0.0
rC11-011100	0/3/0	480.5	0.8	2.0	0.0	0.0/0.0/0.0/0.0
rC12-100000	3/0/0	283.5	9.6	86.9	2.0	41.6/-24.0/-65.2/-45.0

(continued)

Table A.33 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
rC12-111100	3/0/0	194.9	0.6	1.0	0.0	0.0/0.0/0.0/0.0
radiationm18-12-05	0/3/0	<b>201.2</b>	<b>3.4</b>	<b>138.3</b>	<b>9.3</b>	-32.3/-50.0/-46.9/-53.8
radiationm40-10-02	0/3/0	<b>138.1</b>	<b>23.2</b>	228.9	<b>10.8</b>	19.5/-13.8/-8.3/62.2
rail01	0/0/0	-	-	-	-	-/-/-/-
rail02	0/0/0	-	-	-	-	-/-/-/-
rail507	3/0/0	25.1	4.6	1.0	0.0	0.0/0.0/0.0/0.0
ran14x18-disj-8	3/0/0	<b>23.3</b>	0.2	23.3	<b>0.6</b>	-30.9/0.0/-5.6/-50.0
rd-rplusc-21	0/0/2	100.6	44.6	599.8	207.8	-/-/-/-
reblock115	3/0/0	<b>15.7</b>	<b>0.8</b>	<b>75.8</b>	<b>19.3</b>	-30.6/-12.5/-35.6/-70.5
rmatr100-p10	3/0/0	<b>0.9</b>	1.5	<b>4.9</b>	0.0	96.9/0.0/-53.1/0.0
rmatr200-p5	3/0/0	<b>16.5</b>	<b>81.8</b>	<b>6.6</b>	0.0	15.4/-21.5/-69.7/0.0
rocl-4-11	0/0/1	66.4	32.8	799.0	1.0	-/-/-/-
rocl-5-11	0/0/2	90.2	48.9	1553.9	543.1	-/-/-/-
roi2alpha3n4	3/0/0	<b>48.9</b>	<b>5.2</b>	<b>6.0</b>	<b>0.0</b>	26.8/84.3/82.7/100.0
roi5alpha10n8	3/0/0	53.0	<b>80.8</b>	<b>7.0</b>	0.0	7.7/81.2/76.1/0.0
roll3000	0/2/1	<b>49.6</b>	<b>6.7</b>	416.6	78.0	-26.8/-88.1/-84.9/-87.6
rout	0/3/0	13589.3	0.1	36.6	1.7	-3.6/0.0/-3.0/0.0
s100	0/2/0	75.0	2443.5	5.0	0.0	-/-/-/-
s250r10	0/3/0	0.1	336.4	3.0	0.0	0.0/-0.4/0.0/0.0
satellites2-40	0/0/0	-	-	-	-	-/-/-/-
satellites2-60-fs	0/0/0	-	-	-	-	-/-/-/-
savsched1	0/0/0	-	-	-	-	-/-/-/-
sct2	3/0/0	<b>17.4</b>	<b>0.1</b>	<b>6.5</b>	0.0	-48.3/50.0/68.4/0.0
set1ch	3/0/0	<b>38.1</b>	0.1	31.0	1.0	32.0/0.0/0.0/0.0
seymour	3/0/0	16.1	1.4	1.0	0.0	0.0/0.0/0.0/0.0
seymour1	3/0/0	<b>4.0</b>	1.7	<b>3.6</b>	0.0	-12.5/-5.9/55.0/0.0
sing326	3/0/0	57.1	75.3	<b>14.5</b>	<b>0.3</b>	4.2/0.7/30.6/50.0
sing44	3/0/0	21.0	73.1	<b>5.5</b>	0.0	-1.9/2.0/54.5/0.0
snp-02-004-104	0/3/0	<b>59.1</b>	<b>93.7</b>	<b>34.7</b>	<b>2.0</b>	-64.1/69.7/10.6/44.4
sorrell3	3/0/0	39.9	5.2	1.0	0.0	0.0/0.0/0.0/0.0
sp150x300d	3/0/0	<b>1.9</b>	0.1	31.7	<b>1.6</b>	-26.3/0.0/-1.3/-18.8
sp97ar	3/0/0	6414.9	2.8	2.2	0.0	1.5/0.0/8.3/0.0
sp98ar	3/0/0	698.4	1.5	1.0	0.0	0.0/0.0/0.0/0.0
splice1k1	3/0/0	99.0	<b>132.7</b>	<b>9.0</b>	0.0	0.4/11.9/29.1/0.0
square41	0/0/0	-	-	-	-	-/-/-/-
square47	0/0/0	-	-	-	-	-/-/-/-
supportcase10	3/0/0	<b>42.9</b>	<b>377.6</b>	11.1	0.0	65.0/18.5/-1.8/0.0
supportcase12	0/3/0	<b>8.5</b>	<b>36.5</b>	<b>4.0</b>	0.0	-83.5/82.2/81.0/0.0
supportcase18	3/0/0	41.7	1.1	1.0	0.0	0.0/0.0/0.0/0.0
supportcase26	3/0/0	<b>54.6</b>	0.1	<b>7.0</b>	<b>0.0</b>	83.1/0.0/92.2/100.0
supportcase33	0/3/0	97.0	<b>5.8</b>	<b>208.1</b>	<b>49.0</b>	-3.6/-37.9/-48.1/-61.0
supportcase40	3/0/0	<b>48.7</b>	<b>1.1</b>	<b>8.0</b>	0.0	-63.9/21.4/51.8/0.0
supportcase42	0/3/0	<b>9.73e09</b>	<b>89.5</b>	<b>83.3</b>	0.0	-100.0/-83.8/-79.7/0.0
supportcase6	3/0/0	<b>0.7</b>	<b>17.6</b>	<b>5.0</b>	0.0	-14.3/28.5/56.9/0.0
supportcase7	3/0/0	12.4	<b>3.4</b>	<b>8.9</b>	0.0	-1.6/19.0/64.4/0.0
swath	0/0/3	<b>86.4</b>	<b>18.0</b>	685.3	265.9	56.0/-80.0/-75.5/-78.7
swath1	3/0/0	<b>29.5</b>	<b>0.6</b>	<b>60.7</b>	<b>14.1</b>	-49.2/-33.3/-47.9/-85.1
swath3	3/0/0	<b>20.4</b>	<b>0.7</b>	<b>62.3</b>	<b>14.9</b>	-33.8/-14.3/-13.5/-18.8
t1717	2/0/0	30.7	81.5	20.2	0.0	-/-/-/-
tbfp-network	3/0/0	<b>65.6</b>	<b>51.3</b>	<b>18.2</b>	0.0	13.0/-20.3/-39.0/0.0
thor50dday	3/0/0	<b>300.0</b>	171.9	25.8	<b>1.9</b>	-14.1/-6.2/-5.0/-10.5
timtab1	0/3/0	<b>52.5</b>	<b>0.5</b>	<b>117.0</b>	<b>46.4</b>	19.4/37.5/34.9/38.3
timtab2	0/2/1	<b>64.6</b>	<b>4.5</b>	711.2	335.9	11.5/43.0/13.7/-8.7
tr12-30	3/0/0	<b>35.2</b>	0.1	33.2	<b>2.6</b>	51.4/0.0/-4.5/-38.5
traininstance2	0/1/2	<b>37.6</b>	<b>16.3</b>	856.6	58.1	62.2/46.4/44.7/-34.3
traininstance6	0/1/2	<b>817.4</b>	<b>11.2</b>	1158.3	79.9	-61.9/-43.8/-38.7/19.0
trento1	0/3/0	<b>29.1</b>	<b>61.3</b>	<b>8.6</b>	0.0	72.9/-46.2/16.5/0.0
triptim1	0/3/0	<b>0.2</b>	72.6	<b>3.0</b>	0.0	-100.0/5.7/45.5/0.0
uccase12	3/0/0	310.5	257.8	16.3	0.0	9.3/1.4/2.4/0.0
uccase9	3/0/0	194.0	<b>43.0</b>	<b>21.6</b>	<b>0.8</b>	-6.9/21.5/71.9/97.0
uct-subprob	3/0/0	22.7	<b>0.6</b>	<b>12.3</b>	0.0	-1.8/14.3/-17.1/0.0

(continued)

Table A.33 continued

problem	stage 1/2/3	gap(%)	time(s)	iterations	restarts	improvement(%)
unitcal-7	0/0/3	32.4	<b>75.9</b>	768.5	97.1	-3.4/29.2/39.5/58.9
var-smallemercy-m6j6	3/0/0	<b>23.1</b>	<b>5.3</b>	<b>6.3</b>	<b>0.0</b>	54.2/69.9/90.4/100.0
vpm2	3/0/0	462.8	0.1	20.4	0.0	1.5/0.0/0.0/0.0
wachplan	0/3/0	0.0	<b>1.2</b>	<b>22.9</b>	<b>0.0</b>	0.0/25.0/23.9/100.0
Geom. means		(238 instances)	(206 instances)			
FP		63.0	5.7	16.5	1.3	
FP+(3,sv,g,c, $\Delta$ )		<b>61.8</b>	<b>5.5</b>	<b>12.4</b>	<b>0.8</b>	

### A.3. Results for Stage 3 Configurations

From Table A.34 to Table A.36 we compare FP+(3,sv,g,c, $\Delta$ ) (FP3) to its variants with a modified Stage 3 and Xpress as underlying solver. For each instance and each FP3 variant, we report the shifted geometric means out of the three runs with different random seeds for the gap percentage w.r.t the best known solution (gap%), and the running time in Stage 3 (s3 time(s)). If for any instance the number of successful runs is less than three, then the number is reported in a parenthesis in the column gap(%). Moreover, in blue boldface we highlight values that are at least 10% better from the corresponding values found by FP3, and with red italics values that are at least 10% worse. Note that we highlight values only for instances that are solved with all three seeds by both the FP3 variant and FP3. On the last row of each table we show the geometric means of the primal gap, and running time in Stage 3. The geometric means are computed over all instances of our test set that all comparing algorithms found solutions in all three runs. The number of those instances is denoted in the parenthesis next to the term ‘‘Geom. means’’. In Table A.37 and Table A.38 we present similar results with CPLEX as underlying solver, and in Table A.39 and Table A.40 with SCIP.

Table A.34.: Performance of FP3, FP3+s3(3,sd,g), FP3+s3(3,sd,h), and FP3+s3(3,sd,s)

problem	FP3		FP3+s3(3,sd,g)		FP3+s3(3,sd,h)		FP3+s3(3,sd,s)	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
30n20b8	249.0	0.1	249.0	0.1	249.0	0.1	<b>210.1</b>	0.1
academic1metablesmall	inf	228.1	inf	<b>177.3</b>	inf	<b>179.2</b>	inf	<b>186.3</b>
arki001	2.2	0.7	2.0	<i>1.7</i>	2.0	<i>1.1</i>	2.2	<i>1.8</i>
bab2	11.7	11.6	12.6	<b>9.1</b>	<i>15.5</i>	<b>8.8</b>	12.3	<b>8.6</b>
cmflsp50-24-8-8	12.2	5.9	13.5	<i>11.0</i>	12.7	<i>11.6</i>	12.3	<i>12.6</i>
csched007	32.0	1.1	34.4	<b>0.7</b>	34.1	1.2	34.0	<b>0.8</b>
csched008	9.8	0.4	9.8	<b>0.3</b>	9.8	0.4	9.8	<b>0.2</b>
dws008-01	36.9	8.6	<b>21.3</b>	9.4	40.3	<b>4.5</b>	<b>26.4</b>	8.1
germanrr	5.4	0.3	5.4	0.3	5.5	0.3	5.4	0.3
ic97p	12.4	0.1	12.4	0.1	13.5	0.1	12.4	0.1
ic97t	10.7	0.8	11.6	<b>0.6</b>	10.9	<b>0.6</b>	10.7	<b>0.6</b>
icir97p	17.9	1.2	17.2	<i>1.5</i>	<i>20.6</i>	<i>1.5</i>	16.9	1.1
icir97t	9.0	1.8	8.6	1.7	9.0	1.7	9.3	<b>0.7</b>
lectsched-5-obj	1337.8	25.1	1425.2	<b>20.8</b>	1448.6	24.6	1327.0	<b>21.6</b>

(continued)

Table A.34 continued

problem	FP3		FP3+s3(3,sd,g)		FP3+s3(3,sd,h)		FP3+s3(3,sd,s)	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
momentum1	153.4	64.1	<b>106.2</b>	<b>25.0</b>	<b>75.1</b>	<b>10.9</b>	<b>111.0</b>	<b>7.1</b>
mushroom-best	2.37e05	0.6	<b>93553.2</b>	0.6	<b>58773.4</b>	0.6	<b>1.97e05</b>	0.6
neos-1456979	105.2	1.4	99.1	<b>0.8</b>	106.6	<b>1.6</b>	95.5	<b>1.1</b>
neos-1582420	102.4	0.1	<b>68.8</b>	0.1	<b>69.1</b>	0.1	<b>67.6</b>	0.1
neos-2746589-doon	7.4	1.6	<b>5.7</b>	<b>2.1</b>	7.0	<b>2.2</b>	<b>6.0</b>	<b>2.8</b>
neos-3024952-loue	208.4	402.0	196.8	<b>687.0</b>	197.6	402.0	196.4	<b>711.2</b>
neos-3216931-puriri	127.8	46.6	134.8	<b>38.5</b>	<b>99.2</b>	<b>73.8</b>	124.6	<b>41.1</b>
neos-3381206-awhea	4.9	0.1	4.9	0.1	4.9	0.1	4.9	0.1
neos-3656078-kumeu	28.5	10.2	27.1	10.2	<b>24.1</b>	<b>6.0</b>	29.5	<b>5.5</b>
neos-4300652-rahue	162.5	43.6	<b>235.0</b>	47.4	<b>194.0</b>	<b>38.8</b>	<b>144.6</b>	48.4
neos-4338804-snowy	18182.4	0.3	18182.4	0.3	<b>76618.3</b>	0.3	18182.4	0.3
neos-4387871-tavua	48.1	2.5	<b>240.8</b>	2.3	<b>248.0</b>	<b>1.9</b>	<b>216.4</b>	<b>1.6</b>
neos-4532248-waihi	949.4	4.7	949.4	4.5	949.4	4.6	949.4	<b>3.9</b>
neos-4722843-widden	326.6	5.5	333.3	5.5	336.3	5.4	332.0	5.4
neos-5049753-cuanza	48.4	20.0	<b>39.2</b>	20.3	50.9	22.1	<b>40.2</b>	19.1
neos-5104907-jarama	110.7	127.8	68.2 <sup>(2)</sup>	373.9	121.2 <sup>(2)</sup>	341.5	90.6	112.9
neos-5107597-kakapo	38711.4	32.7	<b>34038.5</b>	<b>28.4</b>	40506.5	<b>28.8</b>	<b>10227.7</b>	<b>20.3</b>
neos-5114902-kasavu	50.4	56.7	49.7	<b>42.4</b>	49.3	<b>38.0</b>	<b>23.9</b>	<b>30.6</b>
neos-848589	8.57e05	3.1	<b>1.25e06</b>	3.2	<b>1.34e06</b>	3.2	<b>1.16e06</b>	3.1
neos-960392	27.5	0.8	27.5	0.8	27.5	<b>0.7</b>	27.5	0.8
neos16	0.6	1.7	<b>1.9</b>	<b>2.1</b>	<b>1.4</b>	<b>2.5</b>	<b>1.0</b>	<b>2.8</b>
neos20	59.0	0.8	<b>50.2</b>	<b>0.3</b>	<b>47.2</b>	<b>0.4</b>	<b>50.2</b>	<b>0.4</b>
nh97p	13.0	1.3	<b>10.1</b>	<b>1.0</b>	<b>9.5</b>	<b>1.1</b>	<b>10.0</b>	1.2
nh97t	10.0	2.5	<b>8.9</b>	<b>3.0</b>	10.1	<b>3.0</b>	<b>11.7</b>	<b>2.1</b>
ns1830653	525.3	1.3	527.2	<b>2.3</b>	525.6	<b>0.8</b>	526.9	<b>2.3</b>
physiciansched3-3	907.5	6.1	906.7	<b>8.4</b>	908.7	<b>11.2</b>	906.4	<b>10.3</b>
physiciansched6-2	2.2	0.3	<b>1.9</b>	<b>0.4</b>	2.1	0.3	2.1	0.3
piperout-08	44.8	1.2	<b>81.8</b>	<b>1.6</b>	<b>29.2</b>	<b>0.8</b>	<b>59.8</b>	<b>1.5</b>
piperout-27	37.1	0.9	<b>92.1</b>	<b>1.2</b>	<b>52.4</b>	<b>0.7</b>	39.9	<b>1.3</b>
proteindesign121hz512p9	10.3	0.7	<b>18.1</b>	0.7	<b>18.1</b>	0.7	<b>11.8</b>	<b>0.6</b>
rB12-111111	66.7	0.8	64.2	0.8	64.7	<b>0.7</b>	66.7	<b>0.3</b>
rC10-100001	365.3	0.1	383.5	0.1	371.9	0.1	390.4	0.1
rC12-100000	215.5	0.2	215.5	0.2	215.5	0.2	215.5	0.2
radiationm18-12-05	141.3	0.1	136.8	0.1	136.8	0.1	136.8	0.1
radiationm40-10-02	106.7	0.2	107.1	0.2	106.4	0.2	107.4	0.2
rd-rplusc-21	58.4	0.2	58.5	<b>0.4</b>	57.2	<b>1.2</b>	58.5	0.2
rocl-4-11	54.8	7.4	<b>70.0</b>	7.7	60.4	<b>9.3</b>	56.7	7.8
rocl-5-11	90.6	6.7	91.1	<b>5.0</b>	91.1	<b>7.5</b>	91.3	7.2
satellites2-60-fs	352.6	2.4	352.6	2.4	352.6	2.4	352.6	2.4
supportcase26	387.4	0.1	<b>713.2</b>	0.1	<b>2451.6</b>	0.1	<b>758.5</b>	0.1
supportcase33	84.1	0.1	84.1	0.1	84.1	0.1	84.1	0.1
swath	164.2	3.7	171.7	3.4	<b>209.5</b>	3.4	156.5	<b>2.9</b>
swath1	176.5	0.6	<b>123.6</b>	<b>0.5</b>	167.6	<b>0.5</b>	179.1	<b>0.5</b>
timtab1	70.5	0.3	<b>54.6</b>	0.3	69.2	<b>0.4</b>	71.8	0.3
timtab2	65.2	2.1	<b>58.4</b>	2.0	62.9	2.0	66.4	<b>1.8</b>
traininstance2	19.4	0.1	<b>153.3</b>	0.1	<b>163.2</b>	0.1	<b>37.5</b>	0.1
traininstance6	182.1	0.1	<b>451.7</b>	0.1	<b>451.7</b>	0.1	<b>305.7</b>	0.1
unitcal-7	7.8	3.2	<b>9.2</b>	<b>5.9</b>	<b>8.7</b>	<b>4.7</b>	8.1	3.2
Geom. means(61)	87.0	2.8	<b>94.6</b>	2.8	<b>97.8</b>	<b>2.7</b>	<b>87.2</b>	<b>2.6</b>

Table A.35.: Performance of FP3, FP3+s3(3,sdo,g), FP3+s3(3,sdo,h), and FP3+s3(3,sdo,s)

problem	FP3		FP3+s3(3,sdo,g)		FP3+s3(3,sdo,h)		FP3+s3(3,sdo,s)	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
30n20b8	249.0	0.1	<b>170.9</b>	0.1	<b>182.6</b>	0.1	234.2	0.1
academicmetablesmall	inf	228.1	inf	<b>184.4</b>	inf	<b>299.4</b>	inf	<b>363.0</b>
arki001	2.2	0.7	<b>2.6</b>	<b>1.5</b>	2.3	<b>1.2</b>	2.2	<b>2.4</b>
bab2	11.7	11.6	11.0	<b>27.6</b>	12.1	<b>19.2</b>	11.0	<b>15.1</b>
cmflsp50-24-8-8	12.2	5.9	<b>14.6</b>	<b>18.9</b>	<b>14.6</b>	<b>13.0</b>	<b>14.8</b>	<b>22.7</b>
csched007	32.0	1.1	<b>35.6</b>	<b>2.5</b>	31.0	<b>1.6</b>	<b>28.3</b>	<b>1.8</b>
csched008	9.8	0.4	9.8	<b>0.2</b>	9.8	<b>0.3</b>	9.8	<b>0.3</b>
dws008-01	36.9	8.6	<b>31.8</b>	<b>5.7</b>	38.1	<b>6.7</b>	<b>19.0</b>	<b>6.9</b>
germanrr	5.4	0.3	5.1	<b>0.6</b>	<b>4.2</b>	<b>0.7</b>	<b>4.4</b>	<b>0.7</b>
ic97p	12.4	0.1	13.4	0.1	<b>14.0</b>	0.1	12.6	0.1
ic97t	10.7	0.8	11.7	0.8	10.4	0.8	11.3	<b>0.7</b>
icir97p	17.9	1.2	19.0	<b>1.5</b>	19.4	<b>2.5</b>	18.4	<b>1.5</b>
icir97t	9.0	1.8	9.4	2.0	9.2	1.7	9.2	<b>1.4</b>
lectsched-5-obj	1337.8	25.1	<b>871.8</b>	<b>45.9</b>	<b>973.1</b>	<b>35.0</b>	<b>1034.4</b>	<b>39.5</b>
momentum1	153.4	64.1	<b>121.7</b>	<b>4.0</b>	<b>208.4</b>	<b>92.6</b>	<b>121.7</b>	<b>4.0</b>
mushroom-best	2.37e05	0.6	2.19e05	<b>0.7</b>	<b>52704.2</b>	0.6	<b>1.15e05</b>	0.6
neos-1456979	105.2	1.4	99.6	<b>1.0</b>	100.1	<b>1.1</b>	105.5	<b>1.1</b>
neos-1582420	102.4	0.1	<b>90.0</b>	0.1	<b>58.4</b>	0.1	<b>74.2</b>	0.1
neos-2746589-doon	7.4	1.6	<b>6.0</b>	<b>2.1</b>	7.5	<b>2.0</b>	<b>6.5</b>	1.7
neos-3024952-loue	208.4	402.0	103.0 <sup>(2)</sup>	73.5	102.5 <sup>(2)</sup>	167.3	82.4 <sup>(2)</sup>	166.0
neos-3216931-puriri	127.8	46.6	128.8	<b>57.8</b>	128.8	48.7	134.6	<b>95.6</b>
neos-3381206-awhea	4.9	0.1	4.9	0.1	4.9	0.1	4.9	<b>0.2</b>
neos-3656078-kumeu	28.5	10.2	<b>24.5</b>	10.5	<b>22.0</b>	<b>13.1</b>	<b>21.9</b>	<b>7.1</b>
neos-4300652-rahue	162.5	43.6	<b>182.0</b>	41.8	<b>185.1</b>	39.3	<b>186.5</b>	44.7
neos-4338804-snowy	18182.4	0.3	<b>65762.9</b>	<b>0.1</b>	<b>79152.9</b>	<b>0.1</b>	<b>8421.4</b>	<b>0.2</b>
neos-4387871-tavua	48.1	2.5	<b>114.2</b>	<b>6.3</b>	<b>84.7</b>	<b>5.9</b>	<b>114.2</b>	<b>6.3</b>
neos-4532248-waihi	949.4	4.7	949.4	4.6	949.4	4.4	949.4	4.3
neos-4722843-widden	326.6	5.5	<b>166.8</b>	5.5	<b>167.9</b>	5.5	<b>62.4</b>	5.5
neos-5049753-cuanza	48.4	20.0	45.6	19.7	49.6	19.8	<b>38.0</b>	19.4
neos-5104907-jarama	110.7	127.8	71.9 <sup>(2)</sup>	406.0	131.7	107.3	179.7	102.2
neos-5107597-kakapo	38711.4	32.7	<b>32399.6</b>	<b>28.6</b>	38157.8	<b>28.1</b>	<b>10210.1</b>	<b>21.0</b>
neos-5114902-kasavu	50.4	56.7	<b>35.6</b>	<b>84.6</b>	<b>28.5</b>	60.0	<b>30.8</b>	<b>41.6</b>
neos-848589	8.57e05	3.1	8.43e05	3.1	8.45e05	3.1	<b>1.03e06</b>	3.1
neos-960392	27.5	0.8	<b>35.5</b>	0.8	<b>100.0</b>	0.8	<b>35.5</b>	0.8
neos16	0.6	1.7	<b>1.3</b>	<b>2.6</b>	0.6	<b>2.4</b>	<b>1.3</b>	<b>2.4</b>
neos20	59.0	0.8	60.2	<b>2.2</b>	<b>33.6</b>	<b>0.9</b>	<b>49.8</b>	<b>0.6</b>
nh97p	13.0	1.3	<b>10.7</b>	1.4	<b>9.6</b>	<b>1.5</b>	<b>11.1</b>	1.4
nh97t	10.0	2.5	<b>11.6</b>	<b>4.1</b>	<b>11.9</b>	<b>3.8</b>	<b>11.7</b>	<b>3.2</b>
ns1830653	525.3	1.3	523.7	<b>3.4</b>	525.6	<b>2.2</b>	528.8	<b>2.5</b>
physiciansched3-3	907.5	6.1	907.2	<b>9.7</b>	906.0	<b>12.9</b>	906.3	<b>9.0</b>
physiciansched6-2	2.2	0.3	2.4	0.3	<b>2.6</b>	<b>0.4</b>	<b>2.7</b>	<b>0.4</b>
piperout-08	44.8	1.2	<b>18.0</b>	<b>0.6</b>	<b>21.6</b>	<b>0.6</b>	42.0	<b>1.0</b>
piperout-27	37.1	0.9	<b>109.1</b>	<b>1.2</b>	<b>118.5</b>	<b>1.1</b>	<b>112.2</b>	<b>0.8</b>
proteindesign121hz512p9	10.3	0.7	<b>5.9</b>	0.7	<b>5.9</b>	0.7	<b>5.3</b>	0.7
rB12-111111	66.7	0.8	<b>57.3</b>	0.8	<b>56.0</b>	0.8	<b>59.0</b>	0.8
rC10-100001	365.3	0.1	<b>253.3</b>	0.1	<b>270.9</b>	0.1	<b>267.0</b>	0.1
rC12-100000	215.5	0.2	<b>157.1</b>	0.2	<b>157.4</b>	0.2	<b>156.9</b>	0.2
radiationm18-12-05	141.3	0.1	140.8	0.1	131.8	0.1	<b>126.8</b>	0.1
radiationm40-10-02	106.7	0.2	<b>95.1</b>	0.2	112.9	<b>0.3</b>	<b>94.3</b>	0.2
rd-rplusc-21	58.4	0.2	56.7	<b>4.8</b>	57.0	<b>2.3</b>	57.8	<b>1.0</b>
rocl-4-11	54.8	7.4	<b>76.1</b>	<b>5.2</b>	<b>69.1</b>	<b>4.8</b>	<b>47.8</b>	<b>8.8</b>
rocll-5-11	90.6	6.7	93.1	<b>5.8</b>	93.0	<b>11.0</b>	92.7	<b>11.7</b>
satellites2-60-fs	352.6	2.4	352.6	<b>2.7</b>	352.6	2.5	352.6	2.5
supportcase26	387.4	0.1	<b>4548.0</b>	0.1	<b>6414.4</b>	0.1	<b>7910.8</b>	0.1
supportcase33	84.1	0.1	84.1	0.1	84.1	0.1	84.1	0.1
swath	164.2	3.7	<b>201.7</b>	3.9	177.1	4.0	180.4	3.6

(continued)

Table A.35 continued

problem	FP3		FP3+s3(3,sdo,g)		FP3+s3(3,sdo,h)		FP3+s3(3,sdo,s)	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
swath1	176.5	0.6	<b>141.8</b>	0.6	<b>129.2</b>	0.6	<b>141.8</b>	0.6
timtab1	70.5	0.3	73.2	0.3	63.7	<i>0.4</i>	<i>79.5</i>	0.3
timtab2	65.2	2.1	65.8	<i>2.9</i>	<b>58.4</b>	<i>2.8</i>	64.4	<i>2.8</i>
traininstance2	19.4	0.1	<i>153.3</i>	0.1	<i>163.2</i>	0.1	<i>37.5</i>	0.1
traininstance6	182.1	0.1	<i>343.4</i>	0.1	<i>343.4</i>	0.1	<i>305.7</i>	0.1
unitcal-7	7.8	3.2	<i>8.8</i>	<i>7.1</i>	<i>9.4</i>	<i>8.1</i>	<i>8.9</i>	<i>4.1</i>
Geom. means(60)	85.7	2.5	<i>93.0</i>	<i>2.8</i>	<i>91.5</i>	<i>2.9</i>	<b>83.3</b>	<i>2.7</i>

Table A.36.: Performance of FP3, FP3+mRENS( $c$ ), and FP3+mRENS( $\Delta$ )

problem	FP3		FP3+mRENS( $c$ )		FP3+mRENS( $\Delta$ )	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
30n20b8	249.0	0.1	249.0	0.1	249.0	0.1
academictimetables-small	inf	228.1	inf	<i>693.7</i>	inf	<i>1018.0</i>
arki001	2.2	0.7	<b>0.8</b>	<i>1.0</i>	2.2	<i>1.1</i>
bab2	11.7	11.6	11.7	11.6	11.7	11.6
cmflsp50-24-8-8	12.2	5.9	<b>3.5</b>	<i>36.5</i>	<i>13.6</i>	5.7
csched007	32.0	1.1	32.0	1.1	32.0	1.2
csched008	9.8	0.4	<b>8.3</b>	<b>0.2</b>	9.8	<b>0.1</b>
dws008-01	36.9	8.6	36.9	8.7	36.9	8.7
germanrr	5.4	0.3	<b>3.7</b>	<b>0.2</b>	5.1	<b>0.2</b>
ic97p	12.4	0.1	<b>5.3</b>	0.1	<b>9.9</b>	0.1
ic97t	10.7	0.8	10.7	<i>1.0</i>	10.7	<i>1.2</i>
icir97p	17.9	1.2	<b>9.4</b>	<b>0.1</b>	17.3	<b>0.1</b>
icir97t	9.0	1.8	<b>0.7</b>	<i>2.5</i>	9.5	<b>0.9</b>
lectsched-5-obj	1337.8	25.1	1337.8	25.1	1337.8	25.1
momentum1	153.4	64.1	<b>21.5</b>	<b>27.6</b>	<b>49.2</b>	<b>27.0</b>
mushroom-best	2.37e05	0.6	<b>0.0</b>	<b>0.4</b>	<b>21005.2</b>	<b>0.3</b>
neos-1456979	105.2	1.4	95.5	<b>0.7</b>	113.4	<b>0.6</b>
neos-1582420	102.4	0.1	<b>14.0</b>	<i>0.6</i>	<b>47.2</b>	<i>0.5</i>
neos-2746589-doon	7.4	1.6	<b>5.8</b>	<b>0.9</b>	7.7	<b>0.9</b>
neos-3024952-loue	208.4	402.0	208.4	402.0	208.4	402.0
neos-3216931-puriri	127.8	46.6	<b>67.0</b>	<b>26.2</b>	134.4	<b>17.1</b>
neos-3381206-awhea	4.9	0.1	<b>1.9</b>	0.1	<b>3.5</b>	0.1
neos-3656078-kumeu	28.5	10.2	28.5	10.2	28.5	10.3
neos-4300652-rahue	162.5	43.6	162.5	44.1	162.5	44.6
neos-4338804-snowy	18182.4	0.3	<b>1931.4</b>	0.3	<i>37839.7</i>	0.3
neos-4387871-tavua	48.1	2.5	48.1	2.5	48.1	2.5
neos-4532248-waihi	949.4	4.7	<b>655.5</b>	<i>7.1</i>	949.4	<b>0.8</b>
neos-4722843-widden	326.6	5.5	<b>21.0</b>	<b>0.2</b>	<b>51.8</b>	<b>0.3</b>
neos-5049753-cuanza	48.4	20.0	48.4	20.1	48.4	20.3
neos-5104907-jarama	110.7	127.8	<b>6.8</b>	<b>15.4</b>	<i>141.4</i>	<b>11.7</b>
neos-5107597-kakapo	38711.4	32.7	<b>10653.4</b>	<b>23.9</b>	<b>23587.3</b>	<b>26.0</b>
neos-5114902-kasavu	50.4	56.7	50.4	57.5	50.4	58.2
neos-848589	8.57e05	3.1	<b>3.82e05</b>	<b>0.7</b>	<b>7.66e05</b>	<b>0.6</b>
neos-960392	27.5	0.8	<b>3.6</b>	<i>1.1</i>	<b>2.4</b>	<b>0.4</b>
neos16	0.6	1.7	0.6	1.8	0.6	<i>1.9</i>
neos20	59.0	0.8	59.0	0.8	59.0	0.8
nh97p	13.0	1.3	<b>8.8</b>	<b>1.1</b>	<b>10.9</b>	1.2
nh97t	10.0	2.5	10.0	2.5	10.0	2.5
ns1830653	525.3	1.3	<b>249.4</b>	<i>2.5</i>	527.5	1.4
physiciansched3-3	907.5	6.1	<b>30.5</b>	<i>14.2</i>	<b>370.9</b>	<b>1.4</b>
physiciansched6-2	2.2	0.3	<b>0.7</b>	0.3	2.2	<b>0.2</b>
piperout-08	44.8	1.2	44.8	1.2	44.8	1.2
piperout-27	37.1	0.9	37.1	0.9	37.1	0.9
proteindesign121hz512p9	10.3	0.7	10.3	0.7	10.3	0.7

(continued)

Table A.36 continued

problem	FP3		FP3+mRENS(c)		FP3+mRENS( $\Delta$ )	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
rB12-111111	66.7	0.8	<b>34.5</b>	<b>0.1</b>	64.0	<b>0.1</b>
rC10-100001	365.3	0.1	<b>215.7</b>	0.1	<i>504.6</i>	0.1
rC12-100000	215.5	0.2	<b>147.7</b>	<b>0.1</b>	233.1	<b>0.1</b>
radiationm18-12-05	141.3	0.1	<b>84.6</b>	0.1	135.0	0.1
radiationm40-10-02	106.7	0.2	<b>81.2</b>	0.2	106.3	<b>0.1</b>
rd-rplusc-21	58.4	0.2	58.4	0.2	58.4	0.2
rocl-4-11	54.8	7.4	54.8	7.4	54.8	7.4
rocll-5-11	90.6	6.7	90.6	6.7	90.6	6.8
satellites2-60-fs	352.6	2.4	<b>119.0</b>	<b>0.3</b>	<b>124.8</b>	<b>0.3</b>
supportcase26	387.4	0.1	<b>35.4</b>	0.1	<i>4595.9</i>	0.1
supportcase33	84.1	0.1	80.7	0.1	67.7	0.1
swath	164.2	3.7	164.2	<i>4.3</i>	164.2	<i>4.8</i>
swath1	176.5	0.6	<b>12.8</b>	<b>0.1</b>	<i>241.8</i>	<b>0.1</b>
timtab1	70.5	0.3	<b>37.8</b>	<i>0.5</i>	<b>46.0</b>	<b>0.1</b>
timtab2	65.2	2.1	<b>26.9</b>	<i>4.1</i>	<b>50.6</b>	1.9
traininstance2	19.4	0.1	19.4	0.1	19.4	0.1
traininstance6	182.1	0.1	182.1	0.1	182.1	0.1
unitcal-7	7.8	3.2	<b>4.2</b>	<b>1.6</b>	7.7	<b>1.6</b>
Geom. means(62)	87.4	3.0	<b>37.6</b>	<b>2.7</b>	<b>76.5</b>	<b>2.3</b>

Table A.37.: Performance of FP3, FP3+s3(3,sd,s), FP3+s3(3,sdo,s) with CPLEX

problem	FP3		FP3+s3(3,sd,s)		FP3+s3(3,sdo,s)	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
30n20b8	100.7	0.5	<i>115.4</i>	0.5	94.0	0.5
CMS750-4	294.0	0.1	294.0	0.1	294.0	0.1
academic timetables small	inf	640.4	inf	652.3	inf	<b>538.3</b>
arki001	1.4	0.8	<b>1.2</b>	<b>0.5</b>	<b>1.1</b>	<b>0.3</b>
bab2	27.0	18.5	27.0	18.8	25.8	<i>21.2</i>
bab6	35.1	7.8	35.3	<b>5.1</b>	34.3	<b>7.0</b>
cmflsp50-24-8-8	10.7	6.0	10.3	<b>4.2</b>	10.7	6.1
csched007	45.1	4.6	<b>36.5</b>	4.9	<b>31.6</b>	<i>5.7</i>
dws008-01	43.3	7.6	39.3	8.2	<b>37.2</b>	<b>5.3</b>
eilA101-2	466.4	0.1	466.4	0.1	466.4	0.1
glass4	241.7	0.1	241.7	0.1	252.7	0.1
ic97p	11.3	0.1	11.3	0.1	10.7	0.1
ic97t	8.0	1.9	8.5	<i>2.5</i>	8.6	<i>2.2</i>
icir97p	18.6	0.2	19.8	<b>0.1</b>	<i>21.1</i>	0.2
icir97t	7.3	1.2	7.8	<b>1.0</b>	<i>8.3</i>	<b>0.7</b>
irish-electricity	29.3	25.8	<b>22.0</b>	<b>17.6</b>	<b>21.4</b>	<b>21.2</b>
lectsched-5-obj	2097.1	4.8	2080.5	5.1	<b>1630.3</b>	<i>5.4</i>
markshare1	7.28e05	0.1	7.28e05	0.1	7.28e05	0.1
markshare-4-0	3.08e05	0.1	3.08e05	0.1	3.08e05	0.1
momentum1	389.1	0.1	389.1	0.1	389.1	0.1
neos-1456979	104.5	1.3	96.7	<i>1.7</i>	110.7	<i>3.5</i>
neos-1582420	49.0	1.2	49.0	1.2	<b>41.2</b>	1.3
neos-2746589-doon	25.0	37.6	25.2	<i>65.8</i>	24.4	<i>57.9</i>
neos-2987310-joes	100.0	0.1	100.0	0.1	100.0	0.1
neos-3024952-louie	211.4	18.3	191.8	<i>22.1</i>	<b>81.2</b>	<i>20.7</i>
neos-3216931-puriri	80.8	28.7	<i>91.0</i>	<i>42.1</i>	<i>129.7</i>	<i>84.0</i>
neos-3381206-awhea	2.2	1.7	2.2	<b>1.5</b>	2.2	1.8
neos-3555904-turama	4.3	0.3	4.3	0.3	4.3	0.3
neos-4300652-rahue	206.4	12.1	206.4	<i>14.2</i>	206.4	<i>21.9</i>
neos-4338804-snowy	1087.8	0.1	1087.8	0.1	1087.8	0.1
neos-4387871-tavua	132.4	2.7	<i>150.0</i>	<b>1.7</b>	<b>66.5</b>	<b>1.4</b>
neos-4532248-waihi	788.4	39.9	<i>949.4</i>	<b>26.7</b>	<i>949.4</i>	<b>31.3</b>

(continued)



Table A.37 continued

problem	FP3		FP3+s3(3,sd,s)		FP3+s3(3,sdo,s)	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
neos-5049753-cuanza	26.3	14.5	28.5	<b>22.6</b>	26.4	<b>16.3</b>
neos-5107597-kakapo	961.7	4.0	954.8	3.6	954.8	3.7
neos-848589	1.85e06	0.4	1.85e06	0.4	1.85e06	0.4
neos20	63.5	2.2	59.1	<b>2.5</b>	<b>51.1</b>	2.2
nh97p	10.8	0.1	10.7	0.1	<b>9.6</b>	<b>0.8</b>
nh97t	11.8	2.6	11.0	<b>2.3</b>	11.8	<b>2.2</b>
ns1830653	303.2	0.7	<b>340.9</b>	<b>1.5</b>	<b>362.0</b>	<b>2.5</b>
physiciansched3-3	64.1	19.8	<b>17.9</b>	<b>16.1</b>	<b>115.0</b>	<b>28.3</b>
physiciansched6-2	5.9	2.2	<b>4.7</b>	2.4	6.3	<b>2.5</b>
piperout-08	5.0	1.3	<b>12.5</b>	<b>1.5</b>	<b>12.3</b>	1.2
piperout-27	2.3	1.8	<b>13.8</b>	1.8	<b>12.6</b>	1.7
proteindesign122trx11p8	1.1	0.2	1.1	0.2	1.1	0.2
rB12-111111	65.0	0.4	64.8	<b>0.3</b>	59.5	0.4
rC10-100001	486.6	0.1	485.3	0.1	<b>363.3</b>	0.1
radiationm18-12-05	501.3	0.1	501.3	0.1	501.3	0.1
radiationm40-10-02	10.9	0.1	<b>1550.2</b>	0.1	<b>1550.2</b>	0.1
rd-rplusc-21	101.9	4.0	101.9	4.1	101.9	4.0
rocl-4-11	54.9	5.6	<b>38.0</b>	<b>7.6</b>	52.7	<b>10.3</b>
rocl-5-11	90.6	1.8	91.2	<b>3.4</b>	90.9	<b>3.2</b>
satellites2-40	331.6	0.8	331.6	0.8	331.6	0.8
satellites2-60-fs	610.5	0.1	610.5	0.1	610.5	0.1
swath	52.6	0.1	52.6	0.1	52.6	0.1
swath1	299.8	0.1	299.8	0.1	299.8	0.1
timtab1	74.2	1.6	73.6	<b>1.3</b>	<b>56.5</b>	<b>1.3</b>
timtab2	66.5	1.5	<b>78.8</b>	1.5	67.4	1.4
traininstance2	23.1	0.6	<b>29.8</b>	<b>1.3</b>	<b>33.9</b>	<b>1.6</b>
traininstance6	37.5	0.3	<b>31.8</b>	<b>0.4</b>	<b>33.4</b>	<b>0.4</b>
unitcal-7	46.4	0.1	46.4	0.1	46.4	0.1
Geom. means(60)	93.6	2.2	<b>103.0</b>	<b>2.3</b>	<b>102.0</b>	<b>2.4</b>

Table A.38.: Performance of FP3, FP3+mRENS(c), and FP3+mRENS( $\Delta$ ) with CPLEX

problem	FP3		FP3+mRENS(c)		FP3+mRENS( $\Delta$ )	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
30n20b8	100.7	0.5	100.7	0.5	100.7	0.5
CMS750-4	294.0	0.1	<b>197.5</b>	<b>1.0</b>	<b>185.1</b>	<b>0.9</b>
academic timetables small	inf	640.4	inf	<b>2831.8</b>	inf	<b>4310.5</b>
arki001	1.4	0.8	<b>0.4</b>	<b>1.0</b>	<b>1.6</b>	<b>0.9</b>
bab2	27.0	18.5	27.0	19.7	27.0	<b>20.9</b>
bab6	35.1	7.8	35.1	<b>8.8</b>	35.1	<b>10.1</b>
cmflsp50-24-8-8	10.7	6.0	11.2	<b>7.9</b>	11.4	<b>3.7</b>
csched007	45.1	4.6	45.1	4.6	45.1	4.7
dws008-01	43.3	7.6	43.3	7.7	43.3	7.7
eilA101-2	466.4	0.1	466.4	<b>2.2</b>	466.4	<b>4.3</b>
glass4	241.7	0.1	<b>185.4</b>	<b>4.1</b>	<b>515.2</b>	<b>2.2</b>
ic97p	11.3	0.1	11.3	0.1	11.3	0.1
ic97t	8.0	1.9	8.0	<b>3.7</b>	8.0	<b>7.2</b>
icir97p	18.6	0.2	18.6	0.2	18.6	0.2
icir97t	7.3	1.2	<b>6.4</b>	<b>1.4</b>	7.4	<b>0.6</b>
irish-electricity	29.3	25.8	<b>22.2</b>	<b>18.1</b>	<b>39.7</b>	<b>12.9</b>
lectsched-5-obj	2097.1	4.8	2097.1	5.0	2097.1	5.1
markshare1	7.28e05	0.1	<b>6.07e05</b>	0.1	<b>6.07e05</b>	0.1
markshare-4-0	3.08e05	0.1	2.99e05	0.1	2.99e05	0.1
momentum1	389.1	0.1	<b>41.0</b>	<b>24.1</b>	<b>53.9</b>	<b>17.5</b>

(continued)

Table A.38 continued

problem	FP3		FP3+mRENS(c)		FP3+mRENS( $\Delta$ )	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
neos-1456979	104.5	1.3	109.7	<i>3.6</i>	109.7	<i>4.7</i>
neos-1582420	49.0	1.2	<b>20.8</b>	<i>1.7</i>	<b>41.5</b>	<i>1.8</i>
neos-2746589-doon	25.0	37.6	25.0	38.4	25.0	39.2
neos-2987310-joes	100.0	0.1	<b>42.1</b>	<i>0.9</i>	<b>4.9</b>	<i>1.4</i>
neos-3024952-louie	211.4	18.3	211.4	18.4	211.4	18.5
neos-3216931-puriri	80.8	28.7	<b>61.5</b>	<b>11.1</b>	78.9	<b>7.3</b>
neos-3381206-awhea	2.2	1.7	2.2	<i>3.9</i>	2.2	<i>5.9</i>
neos-3555904-turama	4.3	0.3	<b>2.0</b>	<i>142.0</i>	4.3	<i>102.1</i>
neos-4300652-rahue	206.4	12.1	206.4	<i>13.9</i>	206.4	<i>15.8</i>
neos-4338804-snowy	1087.8	0.1	1087.8	0.1	1087.8	0.1
neos-4387871-tavua	132.4	2.7	132.4	2.7	132.4	2.7
neos-4532248-waihi	788.4	39.9	788.4	<i>63.9</i>	788.4	<i>75.7</i>
neos-5049753-cuanza	26.3	14.5	26.3	<i>17.5</i>	26.3	<i>19.9</i>
neos-5107597-kakapo	961.7	4.0	961.7	4.4	961.7	<i>5.4</i>
neos-848589	1.85e06	0.4	1.85e06	<b>0.1</b>	1.85e06	<b>0.1</b>
neos20	63.5	2.2	63.5	2.2	63.5	2.3
nh97p	10.8	0.1	10.8	0.1	10.8	0.1
nh97t	11.8	2.6	11.8	<i>5.1</i>	11.8	<i>5.3</i>
ns1830653	303.2	0.7	<b>179.3</b>	<b>0.5</b>	<i>461.3</i>	0.7
physiciansched3-3	64.1	19.8	<b>55.6</b>	<i>54.9</i>	<i>239.5</i>	<b>7.2</b>
physiciansched6-2	5.9	2.2	<i>22.6</i>	2.0	<i>22.6</i>	2.4
piperout-08	5.0	1.3	5.0	1.3	5.0	1.4
piperout-27	2.3	1.8	2.3	1.9	2.3	2.0
proteindesign122trx11p8	1.1	0.2	1.1	<i>0.9</i>	1.1	<i>1.8</i>
rB12-111111	65.0	0.4	<b>52.7</b>	<i>2.2</i>	<b>57.3</b>	0.4
rC10-100001	486.6	0.1	<i>1264.5</i>	0.1	<i>1264.5</i>	0.1
radiationm18-12-05	501.3	0.1	<b>219.6</b>	<i>0.5</i>	<b>311.3</b>	<i>0.5</i>
radiationm40-10-02	10.9	0.1	<i>109.8</i>	<i>3.2</i>	<i>139.3</i>	<i>1.8</i>
rd-rplusc-21	101.9	4.0	101.9	<i>4.7</i>	101.9	<i>5.4</i>
rocl-4-11	54.9	5.6	54.9	5.7	54.9	5.7
rocl-5-11	90.6	1.8	90.6	2.0	90.6	<i>2.3</i>
satellites2-40	331.6	0.8	<b>256.2</b>	<b>0.1</b>	<b>256.2</b>	<b>0.1</b>
satellites2-60-fs	610.5	0.1	<b>425.6</b>	<i>0.4</i>	<b>425.6</b>	<i>0.6</i>
swath	52.6	0.1	52.6	<i>2.3</i>	52.6	<i>4.1</i>
swath1	299.8	0.1	<b>92.6</b>	0.1	<b>123.9</b>	0.1
timtab1	74.2	1.6	<b>20.5</b>	<i>2.8</i>	<b>58.3</b>	<i>2.3</i>
timtab2	66.5	1.5	<b>51.6</b>	<i>1.7</i>	69.5	1.4
traininstance2	23.1	0.6	23.1	0.6	23.1	<i>0.7</i>
traininstance6	37.5	0.3	37.5	<i>0.4</i>	37.5	<i>0.4</i>
unitcal-7	46.4	0.1	<b>40.0</b>	<i>0.3</i>	<b>38.6</b>	<i>0.9</i>
Geom. means(60)	93.6	2.2	<b>82.8</b>	<i>3.5</i>	<b>92.8</b>	<i>3.4</i>

Table A.39.: Performance of FP3, FP3+s3(3,sd,s), FP3+s3(3,sdo,s) with SCIP

problem	FP3		FP3+s3(3,sd,s)		FP3+s3(3,sdo,s)	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
10teams	6.6	9.5	7.0	<i>13.8</i>	<b>3.2</b>	<b>7.7</b>
30n20b8	218.5	2.4	197.1	<i>2.7</i>	<b>133.1</b>	<i>2.8</i>
arki001	2.4	2.7	<b>2.1</b>	<i>4.0</i>	<b>2.1</b>	<i>6.5</i>
bab2	10.2	96.3	9.7	92.3	9.7	93.1
bab6	13.4	114.1	13.4	107.2	12.4	<b>92.7</b>
comp21-2idx	1893.3	3.1	<i>15776.6</i>	3.4	<i>18379.4</i>	3.0
csched007	65.2	9.3	<i>82.6</i>	<i>45.2</i>	64.8	<i>38.3</i>
csched008	9.8	9.2	9.8	<b>4.9</b>	9.8	<b>6.8</b>
danoint	197.9	1.2	197.9	1.2	197.9	<b>0.3</b>
eilA101-2	466.4	17.7	466.4	17.4	466.4	17.5

(continued)

Table A.39 continued

problem	FP3		FP3+s3(3,sd,s)		FP3+s3(3,sdo,s)	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
fastxgemm-n2r6s0t2	2714.2	0.1	2714.2	0.1	2714.2	0.1
fiball	10.5	1.1	10.5	<b>1.4</b>	<b>9.1</b>	<b>2.7</b>
hypothyroid-k1	99.6	20.0	99.6	20.1	97.2	19.9
ic97p	14.9	0.1	14.9	0.1	15.0	0.1
ic97t	10.0	1.8	10.6	1.8	9.6	<b>2.5</b>
icir97p	13.2	13.2	13.0	<b>11.2</b>	13.3	<b>6.7</b>
icir97t	5.8	0.5	5.7	<b>0.6</b>	5.4	<b>0.9</b>
lectsched-5-obj	1439.9	259.7	1421.4	<b>192.9</b>	<b>770.4</b>	<b>359.0</b>
milo-v12-6-r2-40-1	134.9	0.5	<b>116.1</b>	<b>0.4</b>	131.3	0.5
momentum1	323.3	1.5	323.3	1.5	323.3	1.5
mushroom-best	1.47e07	0.3	1.47e07	0.3	1.47e07	0.3
neos-1456979	151.2	80.6	<b>117.2</b>	<b>31.1</b>	<b>125.4</b>	<b>40.1</b>
neos-1582420	43.7	0.9	42.9	<b>1.4</b>	<b>31.9</b>	<b>1.3</b>
neos-2657525-crna	966.0	5.3	880.4	<b>8.9</b>	<b>461.4</b>	<b>5.9</b>
neos-2746589-doon	1052.0	602.2	1013.8	<b>389.3</b>	1061.7	<b>523.1</b>
neos-3046615-murg	58.9	0.1	58.9	0.1	58.9	0.1
neos-3216931-puriri	53.6	983.1	56.3	<b>1236.1</b>	54.6	<b>1701.9</b>
neos-3381206-awhea	4.9	5.8	4.9	<b>6.7</b>	4.9	<b>0.9</b>
neos-3656078-kumeu	725.4 <sup>(2)</sup>	947.9	734.8 <sup>(2)</sup>	1250.6	753.0 <sup>(2)</sup>	1126.4
neos-4338804-snowy	1455.3	0.1	<b>1016.4</b>	0.1	<b>11406.3</b>	<b>0.2</b>
neos-4387871-tavua	71.9	6.5	<b>214.5</b>	<b>3.9</b>	<b>176.0</b>	<b>11.5</b>
neos-4532248-waihi	949.4	239.8	949.4	243.0	949.4	<b>175.8</b>
neos-4722843-widden	61.1	5.2	61.1	5.2	<b>42.4</b>	5.1
neos-5107597-kakapo	46596.4	0.4	<b>38602.9</b>	<b>0.6</b>	<b>36797.7</b>	<b>0.5</b>
neos-848589	1.85e06	61.6	1.85e06	61.5	1.85e06	62.2
neos16	1.1	5.4	<b>0.7</b>	<b>16.0</b>	<b>1.6</b>	<b>15.1</b>
neos20	38.2	0.7	38.2	0.7	<b>50.8</b>	<b>3.7</b>
nh97p	8.7	8.6	<b>7.0</b>	<b>10.2</b>	<b>10.3</b>	<b>16.4</b>
nh97t	8.2	3.4	8.7	<b>5.6</b>	9.1	<b>2.9</b>
ns1208400	0.0	277.9	0.0	<b>203.9</b>	0.0	<b>143.6</b>
ns1830653	444.3	6.5	469.3	<b>3.9</b>	400.4	<b>4.9</b>
physiciansched3-3	1042.3 <sup>(2)</sup>	635.4	1042.4	180.8	1042.4	277.2
physiciansched6-2	67.5	26.7	68.4	<b>36.2</b>	62.0	<b>33.2</b>
piperout-08	56.1	9.9	<b>95.9</b>	<b>11.9</b>	<b>140.6</b>	<b>11.2</b>
piperout-27	25.8	56.3	<b>29.1</b>	57.3	25.0	<b>63.3</b>
proteindesign121hz512p9	4.4	71.0	<b>3.9</b>	<b>39.5</b>	<b>7.5</b>	66.0
proteindesign122trx11p8	1.8	42.0	1.8	41.8	1.8	42.0
rB12-111111	76.0	1.4	74.4	1.5	71.8	<b>1.8</b>
rC10-100001	1256.5	0.3	1255.7	0.3	1258.2	<b>0.4</b>
radiationm18-12-05	413.5	0.4	413.5	0.4	401.3	0.4
radiationm40-10-02	333.6	1.7	332.9	1.7	320.9	1.7
rd-rplusc-21	101.5	9.6	101.5	<b>13.9</b>	102.6	<b>22.0</b>
reblock115	100.0	0.7	100.0	0.7	100.0	0.7
rocl-4-11	69.1	18.6	<b>41.8</b>	<b>16.3</b>	<b>56.7</b>	18.9
rocl-5-11	98.9	27.8	98.9	<b>24.9</b>	98.9	26.7
roll3000	47.0	0.6	48.7	<b>0.4</b>	43.7	<b>1.7</b>
supportcase42	inf	0.3	inf	<b>0.4</b>	inf	<b>0.4</b>
swath	55.7	0.2	55.7	0.2	55.7	0.2
swath1	207.1	1.5	192.1	1.6	<b>252.7</b>	1.5
swath3	167.7	1.6	166.0	1.7	<b>226.8</b>	<b>1.8</b>
timtab1	57.0	0.1	59.3	0.1	58.2	<b>0.7</b>
timtab2	60.2	4.5	60.2	<b>2.9</b>	<b>51.3</b>	<b>3.5</b>
traininstance2	29.6	6.4	<b>21.9</b>	<b>30.7</b>	<b>21.9</b>	<b>30.7</b>
traininstance6	464.1	0.7	<b>584.0</b>	0.7	<b>583.8</b>	0.7
unitcal-7	13.5	32.3	13.7	<b>50.5</b>	12.3	<b>70.3</b>
Geom. means(63)	164.3	6.8	<b>169.4</b>	<b>7.2</b>	<b>172.2</b>	<b>7.6</b>

Table A.40.: Performance of FP3, FP3+mRENS( $c$ ), and FP3+mRENS( $\Delta$ ) with SCIP

problem	FP3		FP3+mRENS( $c$ )		FP3+mRENS( $\Delta$ )	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
10teams	6.6	9.5	<b>2.5</b>	<i>78.6</i>	<b>3.9</b>	<i>20.7</i>
30n20b8	218.5	2.4	<b>193.7</b>	<b>1.7</b>	218.5	<b>1.7</b>
arki001	2.4	2.7	<b>0.5</b>	2.7	2.4	<b>2.0</b>
bab2	10.2	96.3	10.2	97.5	10.2	98.8
bab6	13.4	114.1	13.4	115.0	13.4	115.9
comp21-2idx	1893.3	3.1	1893.3	3.2	1893.3	3.3
csched007	65.2	9.3	<b>48.6</b>	<i>19.3</i>	<b>57.9</b>	<i>20.0</i>
csched008	9.8	9.2	<b>7.7</b>	<b>5.2</b>	9.8	<b>4.7</b>
danoimt	197.9	1.2	<b>8.6</b>	<i>6.8</i>	197.9	1.2
eilA101-2	466.4	17.7	466.4	<i>19.8</i>	466.4	<i>21.8</i>
fastxgemm-n2r6s0t2	2714.2	0.1	<b>370.2</b>	0.1	2714.2	0.1
fiball	10.5	1.1	9.6	<b>0.1</b>	9.6	<b>0.2</b>
hypothyroid-k1	99.6	20.0	<b>86.1</b>	<b>7.8</b>	95.2	<b>7.8</b>
ic97p	14.9	0.1	<b>5.9</b>	0.1	<b>11.2</b>	0.1
ic97t	10.0	1.8	10.0	1.8	10.0	1.8
icir97p	13.2	13.2	13.2	13.2	13.2	13.3
icir97t	5.8	0.5	<b>0.9</b>	<i>5.0</i>	<i>6.5</i>	<i>0.6</i>
lectsched-5-obj	1439.9	259.7	1439.9	259.8	1439.9	259.8
milo-v12-6-r2-40-1	134.9	0.5	<i>181.9</i>	<b>0.3</b>	<b>105.7</b>	<b>0.3</b>
momentum1	323.3	1.5	<b>15.5</b>	<i>63.1</i>	<b>42.6</b>	<i>12.8</i>
mushroom-best	1.47e07	0.3	<b>2.88e05</b>	<b>0.2</b>	<b>2.88e05</b>	<b>0.2</b>
neos-1456979	151.2	80.6	151.2	83.9	151.2	<i>89.6</i>
neos-1582420	43.7	0.9	<b>10.5</b>	<i>3.2</i>	<b>38.6</b>	<b>0.7</b>
neos-2657525-crna	966.0	5.3	966.0	5.6	966.0	<i>6.1</i>
neos-2746589-doon	1052.0	602.2	1052.0	602.5	1052.0	602.7
neos-3046615-murg	58.9	0.1	58.9	0.1	58.9	0.1
neos-3216931-puriri	53.6	983.1	53.6	985.5	53.6	988.1
neos-3381206-awhea	4.9	5.8	4.9	5.9	4.9	6.0
neos-3656078-kumeu	725.4 <sup>(2)</sup>	947.9	725.4 <sup>(2)</sup>	948.0	725.4 <sup>(2)</sup>	948.1
neos-4338804-snowy	1455.3	0.1	1455.3	0.1	1455.3	0.1
neos-4387871-tavua	71.9	6.5	71.9	6.6	71.9	6.6
neos-4532248-waihi	949.4	239.8	949.4	253.1	949.4	261.4
neos-4722843-widden	61.1	5.2	<b>36.1</b>	<b>1.6</b>	<b>43.5</b>	<b>1.7</b>
neos-5107597-kakapo	46596.4	0.4	46596.4	<i>1.2</i>	46596.4	<i>1.9</i>
neos-848589	1.85e06	61.6	<b>4.34e05</b>	68.3	1.85e06	<b>4.1</b>
neos16	1.1	5.4	1.1	6.0	1.1	<i>7.6</i>
neos20	38.2	0.7	38.2	0.7	38.2	0.7
nh97p	8.7	8.6	8.7	8.6	8.7	8.6
nh97t	8.2	3.4	8.2	3.4	8.2	3.5
ns1208400	0.0	277.9	0.0	<i>360.2</i>	0.0	254.7
ns1830653	444.3	6.5	<b>190.2</b>	<i>11.0</i>	435.5	<b>5.8</b>
physiciansched3-3	1042.3 <sup>(2)</sup>	635.4	1042.3 <sup>(2)</sup>	693.0	1042.3 <sup>(2)</sup>	705.1
physiciansched6-2	67.5	26.7	67.5	27.2	67.5	27.8
piperout-08	56.1	9.9	56.1	10.0	56.1	10.0
piperout-27	25.8	56.3	25.8	56.4	25.8	56.4
proteindesign121hz512p9	4.4	71.0	4.4	71.4	4.4	71.8
proteindesign122trx11p8	1.8	42.0	1.8	42.3	1.8	42.6
rB12-111111	76.0	1.4	81.0	<b>1.2</b>	68.9	<b>0.2</b>
rC10-100001	1256.5	0.3	<b>279.4</b>	<b>0.1</b>	<b>409.8</b>	<b>0.1</b>
radiationm18-12-05	413.5	0.4	<b>171.7</b>	<b>0.1</b>	<b>166.6</b>	<b>0.1</b>
radiationm40-10-02	333.6	1.7	<b>239.2</b>	<b>1.3</b>	<b>245.8</b>	<b>1.4</b>
rd-rplusc-21	101.5	9.6	101.5	10.0	101.5	10.3
reblock115	100.0	0.7	<b>9.9</b>	<i>38.6</i>	<b>10.7</b>	<i>1.8</i>
rocl-4-11	69.1	18.6	69.1	20.1	69.1	<i>22.6</i>
rocl-5-11	98.9	27.8	98.9	29.3	98.9	<i>31.6</i>
roll3000	47.0	0.6	<b>17.9</b>	<i>1.0</i>	46.8	<b>0.3</b>

(continued)

Table A.40 continued

problem	FP3		FP3+mRENS( <i>c</i> )		FP3+mRENS( $\Delta$ )	
	gap(%)	s3 time(s)	gap(%)	s3 time(s)	gap(%)	s3 time(s)
supportcase42	inf	0.3	inf	<b>0.2</b>	inf	<b>0.2</b>
swath	55.7	0.2	<b>45.5</b>	<b>3.9</b>	<b>62.5</b>	<b>4.4</b>
swath1	207.1	1.5	<b>28.1</b>	<b>0.3</b>	<b>179.3</b>	<b>0.4</b>
swath3	167.7	1.6	<b>13.2</b>	<b>0.5</b>	155.5	<b>0.4</b>
timtab1	57.0	0.1	<b>23.6</b>	<b>1.2</b>	60.4	0.1
timtab2	60.2	4.5	<b>48.2</b>	<b>13.4</b>	57.0	<b>1.9</b>
traininstance2	29.6	6.4	29.6	6.5	29.6	6.5
traininstance6	464.1	0.7	464.1	0.7	464.1	0.7
unitcal-7	13.5	32.3	13.5	32.5	13.5	32.7
Geom. means(63)	164.3	6.8	<b>98.7</b>	<b>8.5</b>	<b>135.2</b>	<b>6.5</b>