SATISFIABILITY
Research on the influence of 3SAT transformation on the performance of solvers

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Abstract

The performance of 3SAT-solvers may be improved when an instance has first been transformed. Several combinations of transformations have been applied to various instances and their results measured. This research shows that improvements can be made, yet these improvements seem to occur at random. As the results show, translation methods which are using preprocessing have achieved great improvements in solving-time. For Minisat the number of timeouts can be decreased drastically by using preprocessing.

Contents

Chapter 1

Introduction

This report describes the findings and results gathered from research on the influence of different 3SAT(also called 3CNF) transformations on the performance of several solvers for the Boolean satisfiability problem. The so-called Boolean satisfiability problem or simply SAT is the first problem that was proven to be NP-complete. An instance of SAT consists of a Boolean expression containing only variables, brackets and the operators AND, OR and NOT. The problem lies in finding a truth-assignment to all variables that turns the whole expression true. Every instance of SAT can be written down as a conjunction of clauses by applying De Morgan's laws. A conjunction connects clauses solely by AND-operators. A clause itself is a disjunction of literals, meaning that literals in a clause are only connected through OR-operators. Literals are either variables or negated variables. The expression that is so formed is said to be written in conjunctive normal form or CNF. A Boolean expression in CNF could look something like:

$$(A \vee B \vee C \vee D) \wedge (C \vee B) \wedge (\neg E \vee C \vee D \vee B \vee F)$$

Where $\vee$, $\wedge$ and $\neg$ respectively stand for the OR-, AND- and NOT-operator. Such CNF-expressions can in turn be written as expressions in k-CNF (where k is an integer greater than or equal to 3). Every clause in k-CNF consists of at most k literals. This transformation can be done in several ways, for instance through the use of De Morgan's laws. However this transformation is not linear in time. This research concentrates on linear methods. It is of great importance that after transformation the expression remains satisfiability equivalent. This means that an expression that is satisfiable, is also satisfiable after transformation and vice versa. The new expression does not necessarily have to be logically equivalent due to additional variables introduced during transformation.

Because SAT has been around for quite some time, a lot of research has already been conducted on the topic. Hence, there are several solvers for the decision-problem. Each solver uses its own strategy for dealing with a problem as efficient as possible. To create some form of uniformity and to be able to make a comparison between the qualities of different solvers, the Center for Discrete Mathematics and Theoretical Computer Science (DIMACS) has come up with a standard file-format for storing SAT-instances[1]. This research uses this file-format in CNF not only as input, but also for output after a transformation has been made. A fragment of a SAT-instance in CNF stored in DIMACS-format could look something like:

```
c SAT instance in DIMACS CNF input format.
p cnf 512 10469
1 0
2 0
3 0
4 0
1 30 31 32 33 34 35 36 0
37 38 39 40 41 42 43 44 0
...
```

The file optionally starts with some lines starting with `c`. These lines are used for comment. After that comes the problem-line, starting with `p`. This line denotes the applied normal form, de maximum variable index en the number of clauses. In this fragment, the applied normal form is CNF, de maximum number of variables equals 512 and there are 10469 different clauses (hence, the fragment shows only a very small portion of the whole file. The rest of the file consists of positive and negative integers. Positive integers denote variables, negative integers denote negated variables. The end of a clause is indicated by the number `0`. This way a clause can be stored on more than one line in the file.

For SAT-instances there are three categories. The first category contains random instances. Instances in this category can be made by randomly assembling clauses of a predetermined maximum length using a predetermined number of variables. Next comes a category of industrial instances. These instances stem from real-life problems that may occur in practice. Finally there is the category of handmade or crafted instances. These problems are specially crafted to be as difficult as possible for the strategies used by the various solvers. The research only focuses on problems from this last category as they are very difficult yet may lead to significant gains when transformed.

[1] http://www.cs.ubc.ca/∼hoos/SATLIB/Benchmarks/SAT/satformat.ps

Chapter 2

The Program

The program reads a CNF-file and then applies several transformation to it. The purpose of the program is to change a CNF-instance into a 3CNF-instance. This means that the output of the program is a new CNF-file containing clauses with a length of at most three. The internal representation of the CNF-file in the program is a clause-table and a literal-table. The clause-table denotes for every clauses the literals contained in that clause and the literal-table keeps track of the clauses in which a literal is contained. Below is a table giving an idea of this internal representation:

CNF-file	clause table	literal table
`p cnf 6 3`	$[1]$	$[1, 0]$
`1 0`	$[2, 3, -4]$	$[-1, 2]$
`2 3 -4 0`	$[-1, 5, 6]$	$[2, 1]$
`-1 5 6 0`		$[-2]$
		$[3, 1]$
		$[-3]$
		$[4]$
		$[-4, 1]$
		$[5, 2]$
		$[-5]$
		$[6, 2]$
		$[-6]$

The different transformations will be discussed hereafter.

2.1 Unit clause removal

This method removes so-called unit clauses. Unit clauses are clauses containing only one literal. First off, this method gathers all clauses containing only one literal and places them in a set. This set is then traversed and every clause in it is removed from the clause-table. All other clauses containing the same literal are also removed and from clauses containing the negation of the literal, the negation is removed. This last step could lead to new clauses with only one literal and so these are added to the set along the way for further processing. This method traverses the clause-table one time to gather the set of unit clauses. Then the literal-table is used to index the clauses and literals to be removed. Finally the literal-table is updated. The three steps carried out for each clause in the set are shown schematically below. P herein denotes a literal in a unit clause.

$$\begin{array}{rcl} (P) & \rightarrow & \cancel{(P)} \\ (\ldots P \ldots) & \rightarrow & \cancel{(\ldots P \ldots)} \\ (\ldots \neg P \ldots) & \rightarrow & (\ldots \cancel{\neg P} \ldots) \end{array}$$

2.2 Less redundant transformation

The CNF-file is preprocessed to diminish the amount of redundancy of a straightforward 3CNF-transformation. The method looks for the pair of literals that is most common in all clauses with a length of over three. This pair is then replaced by a dummy-variable and three new clauses are added. The method is repeated until no such pair of literals is found anymore [1]. First a temporary clause-table and literal-table is constructed for all clauses which contain more than three literals. Then the temporary literal-table is traversed to find the most occurring literal. Next the temporary literal-table is traversed again to find the literal which occurs the most in combination with the most occurring literal. Now the pair of literals can be replaced. Finally the literal-table is updated. This whole process is repeated until no pair of literals is found anymore. This method can be time-consuming if there are many pairs of literals to be replaced. In the supplied example below $\neg X_2 \vee X_4$ is the most common pair of literals and is therefore replaced by dummy-variable D_1:

$$\begin{array}{r} X_1 \vee \neg X_2 \vee \neg X_3 \vee X_4 \vee \neg X_5 \\ X_1 \vee \neg X_2 \vee \neg X_3 \vee X_4 \vee X_6 \\ \neg X_1 \vee \neg X_2 \vee \neg X_3 \vee X_4 \vee \neg X_6 \\ \neg X_1 \vee \neg X_2 \vee X_4 \vee X_5 \vee X_6 \end{array}$$

becomes:

$$\begin{array}{rll}
X_1 \vee & D_1 & \vee \neg X_3 \vee \neg X_5 \\
X_1 \vee & D_1 & \vee \neg X_3 \vee X_6 \\
\neg X_1 \vee & D_1 & \vee \neg X_3 \vee \neg X_6 \\
\neg X_1 \vee & D_1 & \vee X_5 \vee X_6 \\
 & D_1 & \vee X_2 \\
 & D_1 & \vee \neg X_4 \\
\neg & D_1 & \vee \neg X_2 \vee X_4
\end{array}$$

2.3 Methods of transformation

Below, three methods for transforming SAT-instances from CNF to 3CNF will be described. After transformation each clause has a length of at most three. Clauses in the original instance with a length smaller than or equal to three are untouched.

2.3.1 Chinese Method

This method distinguishes between two types of clauses, those having an even number of literals and those having an odd number of literals. For clauses with an even number p of clauses, $\frac{p}{2}$ new variables are introduced. For clauses with an odd number p of clauses, $\frac{p+1}{2}$ new variables are introduced. Then in both cases the original clause is transformed into p new clauses. The clause-table is traversed one time, for every clause with more than three literals, the method is applied. Finally the literal-table is updated. For an elaborate description of this method, see [2]. There now follow two examples, one for each case just described:

Even length:

$$X_1 \vee X_2 \vee X_3 \vee X_4 \vee X_5 \vee X_6$$

becomes:

$$\begin{array}{r}
X_1 \vee D_1 \vee D_3 \\
X_2 \vee \neg D_1 \vee D_2 \\
X_3 \vee \neg D_2 \vee D_3 \\
X_4 \vee D_2 \vee \neg D_3 \\
X_5 \vee D_1 \vee \neg D_2 \\
X_6 \vee \neg D_1 \vee \neg D_3
\end{array}$$

Odd length:

$$X_1 \vee X_2 \vee X_3 \vee X_4 \vee X_5$$

becomes:

$$\begin{aligned} X_1 \vee D_1 \vee D_2 \\ X_2 \vee \neg D_1 \vee D_2 \\ X_3 \vee D_1 \vee \neg D_2 \\ X_4 \vee \neg D_1 \vee D_3 \\ X_5 \vee \neg D_2 \vee \neg D_3 \end{aligned}$$

2.3.2 Snake method

A clause that is too long for 3CNF is unrolled as it seems using various dummy-variables. The first two literals are put together with dummy variable D_1 into a new clause. The negation of D_1, the next literal from the clause and a new dummy-variable D_2 together form the next clause. This unrolling continues until finally the last two literals from the original clause are put together with the negation of the dummy-variable D_n that was last introduced. The clause-table is traversed one time, for every clause with more than three literals, the method is applied. Finally the literal-table is updated. The snake method is shown below. X_1 through X_8 denote the literals from the original clause and D_1 through D_5 are dummy-variables.

$$X_1 \vee X_2 \vee X_3 \vee X_4 \vee X_5 \vee X_6 \vee X_7 \vee X_8$$

becomes:

$$\begin{array}{llllllllllll}
X_1 \vee X_2 \vee & D_1 & & & & & & & & & & \\
& \neg D_1 & \vee X_3 \vee & D_2 & & & & & & & & \\
& & & \neg D_2 & \vee X_4 \vee & D_3 & & & & & & \\
& & & & & \neg D_3 & \vee X_5 \vee & D_4 & & & & \\
& & & & & & & \neg D_4 & \vee X_6 \vee & D_5 & & \\
& & & & & & & & & \neg D_5 & \vee X_7 \vee X_8 &
\end{array}$$

After this method there exists a form of postprocessing where so-called blocked clauses are added. A clause C is called blocked when it contains a literal such that every clause containing that same literal also contains the negation of another literal in C. Please also see [3] for an elaboration on this. This postprocessingphase is optional. Postprocessing is an additional step in the snake method itself. No extra traversal of the clause-table or literal-table is involved. Continuing the example above, the blocked clauses that can be added are:

$$\neg D_1 \vee \neg X_1$$
$$\neg D_1 \vee \neg X_2$$
$$D_1 \vee \neg D_2$$
$$\neg D_2 \vee \neg X_3$$
$$D_2 \vee \neg D_3$$
$$\neg D_3 \vee \neg X_4$$
$$D_3 \vee \neg D_4$$
$$\neg D_4 \vee \neg X_5$$
$$D_4 \vee \neg D_5$$
$$\neg D_5 \vee \neg X_6$$

2.3.3 Pyramid method

This method chops each clause longer than three literals into to portions of two literals and adds to each of these pairs a dummy-variable. The negations of all of those dummy-variables together form a new clause. This clause could be longer than three literals by itself, so it may have to be transformed also. The clause-table is traversed one time, for every clause with more than three literals, the method is applied. Finally the literal-table is updated. Below are two examples, one with even length and one with odd length. Clauses set in **bold** are too long for 3CNF.

Even length:

$$\mathbf{X_1} \vee \mathbf{X_2} \vee \mathbf{X_3} \vee \mathbf{X_4} \vee \mathbf{X_5} \vee \mathbf{X_6} \vee \mathbf{X_7} \vee \mathbf{X_8}$$

becomes:

$$X_1 \vee X_2 \vee D_1$$
$$X_3 \vee X_4 \vee D_2$$
$$X_5 \vee X_6 \vee D_3$$
$$X_7 \vee X_8 \vee D_4$$
$$\neg \mathbf{D_1} \vee \neg \mathbf{D_2} \vee \neg \mathbf{D_3} \vee \neg \mathbf{D_4}$$

This last clause is too long and will be transformed into:

$$\neg D_1 \vee \neg D_2 \vee D_5$$
$$\neg D_3 \vee \neg D_4 \vee \neg D_5$$

After this method there exist two methods for postprocessing where once again blocked clauses are added. It is very important that only one of these methods is applied to ensure satisfiability equivalence. Same as for the snake method, postprocessing is an additional step. No extra traversal of the clause-table or literal-table is involved. Continuing with the above example, it is possible to add either one of the following sets of blocked clauses.

Postprocessing 1:

$$\begin{aligned} D_1 &\vee D_2 \\ D_1 &\vee D_3 \\ D_1 &\vee D_4 \\ D_1 &\vee \neg D_5 \\ D_2 &\vee D_3 \\ D_2 &\vee D_4 \\ D_2 &\vee \neg D_5 \\ D_3 &\vee D_4 \end{aligned}$$

Postprocessing 2:

$$\begin{aligned} \neg D_1 &\vee \neg X_1 \\ \neg D_2 &\vee \neg X_3 \\ \neg D_3 &\vee \neg X_5 \\ \neg D_4 &\vee \neg X_7 \\ \neg D_1 &\vee \neg X_2 \\ \neg D_2 &\vee \neg X_4 \\ \neg D_3 &\vee \neg X_6 \\ \neg D_4 &\vee \neg X_8 \\ \neg D_5 &\vee D_1 \\ \neg D_5 &\vee D_2 \end{aligned}$$

Odd length:

$$\mathbf{X_1} \vee \mathbf{X_2} \vee \mathbf{X_3} \vee \mathbf{X_4} \vee \mathbf{X_5} \vee \mathbf{X_6} \vee \mathbf{X_7}$$

becomes:

$$\begin{aligned} X_1 \vee X_2 &\vee D_1 \\ X_3 \vee X_4 &\vee D_2 \\ X_5 \vee X_6 &\vee D_3 \\ \mathbf{X_7} \vee \neg\mathbf{D_1} \vee \neg\mathbf{D_2} &\vee \neg\mathbf{D_3} \end{aligned}$$

This last clause is too long and will be transformed into:

$$X_7 \vee \neg D_1 \vee D_4$$
$$\neg D_2 \vee \neg D_3 \vee \neg D_4$$

Postprocessing 1:

$$D_1 \vee D_2$$
$$D_1 \vee D_3$$
$$D_1 \vee \neg X_7$$
$$D_1 \vee \neg D_4$$
$$D_2 \vee D_3$$
$$D_2 \vee \neg X_7$$
$$D_3 \vee \neg X_7$$
$$\neg D_4 \vee \neg X_7$$

Postprocessing 2:

$$\neg D_1 \vee \neg X_1$$
$$\neg D_1 \vee \neg X_2$$
$$\neg D_2 \vee \neg X_3$$
$$\neg D_2 \vee \neg X_4$$
$$\neg D_3 \vee \neg X_5$$
$$\neg D_3 \vee \neg X_6$$
$$\neg D_4 \vee \neg X_7$$
$$\neg D_4 \vee D_1$$

Chapter 3

Research

Primary selection Through the SAT Competition website[1] a total of 244 instances were selected from the *crafted* benchmarks of 2005 [4]. These instances were selected based on the fact that they were solvable by both solvers used during this research. In total, 149 satisfiable *(SAT)* and 59 unsatisfiable *(UNSAT)* instances were selected as well as 36 instances which were known to reach the timeout threshold of 20 minutes or 1200 seconds *(TO)*.

Translation Each of these 244 instances was then translated using the aforementioned methods after being subject to unit clause removal. Through applicable combinations of all methods, there were now 12 copies of each instance. One standard, untouched copy for reference and 11 translations. The acronyms in italics correspond to the cloumns in the tables used in the next sections.

1. Reference *(REF)*
2. Snake *(S)*
3. Pyramid *(PY)*
4. Chinese method *(CH)*
5. Preprocessing – Snake *(PRS)*
6. Preprocessing – Pyramid *(PRPY)*
7. Snake – Postprocessing *(SP)*
8. Pyramid – Postprocessing 1 *(PYP1)*
9. Pyramid – Postprocessing 2 *(PYP2)*

[1] http://www.satcompetition.org/2005/

10. Preprocessing – Snake – Postprocessing *(PRSP)*

11. Preprocessing – Pyramid – Postprocessing 1 *(PRPYP1)*

12. Preprocessing – Pyramid – Postprocessing 2 *(PRPYP2)*

Running and recording With 12 copies of 244 instances on 2 solvers, a total of 5856 tests were run over a period of several weeks and their respective times recorded.

Secondary selection After the tests were run, all times were scrutinized. It turned out that no performance increase was reached solving the *TO*–category of instances, therefore these results were ignored. All instances in this category, reached the same timeout threshold after translation.

Among the instances in both the *SAT*– and *UNSAT*–category there were some where the average processing time in both solvers and all copies was less than 5 seconds. Analysis of these instances would be unreliable because of the short times with respect to the precision of the timing. These instances were ignored as well.

Special attention has been paid to copies that reached the timeout threshold of 20 minutes or 1200 seconds, either in standard or translated form. Three cases can be discerned, for which analysis is unreliable:

1. If the reference copy records a time just below the threshold, it is not uncommon for a translation to go beyond the threshold and record a timeout. Such a case is recorded as decreased performance. However, it may have recorded a time just above the threshold or it may have recorded a time that was much longer if it were allowed to run indefinitely. No calculation of any slowdown factor can be made in such a case.

2. If the reference copy reached the timeout threshold but a translation were to record a time, a performance increase was recorded with a calculated improvement percentage of 100

3. If both the reference and a translation reached the threshold, no calculations can be made whatsoever.

Eventually, analysis was performed on 109 *SAT*–instances and 39 *UNSAT*–instances, adding up to a total of 148 instances or 1776 copies.

Analysis Basically, all analysis was performed by relating each recorded time or timeout to the recorded time of the reference copy of the instance. Analysis on the 148 instances that were left after secondary selection was performed using the following three criteria:

1. **Percentage timeouts**
   The number of timeouts divided by the total number of instances.

2. **Percentage improved**
   Dividing the number of instances that recorded a time less or equal to the reference time by the total number of instances.

3. **Average improvement factor**
   The average of all factors of those instances that recorded an improvement.

3.1 Results

The results are listed below per solver per criterion.

3.1.1 Percentage timeouts

The reference copy recorded 0.7 % timeouts in March_dl [1] and 8.1 % in MiniSAT [5].

Table 3.1: March_dl, top 3 percentage timeouts (reference: 0.7 %)

1. PRPYP1 (16.2 %)
2. PRPYP2 – PRS (19.6 %)
3. PRPY (20.9 %)

Table 3.2: MiniSAT, top 3 percentage timeouts (reference: 8.1 %)

1. PRPYP1 (1.4 %)
2. PRPY – PRPYP2 (2.0 %)
3. PRS – PRSP (3.4 %)

It is remarkable to see how all translations recorded much more timeouts than the reference copy when solved by March_dl, where the opposite happened when solved by MiniSAT. The translations recorded lower percentages than the reference copy when solved by MiniSAT. In both cases PRPYP1 scored the lowest percentage timeouts. The low scores on both solvers for PRPYP1 is of interest to research where timeouts may pose a problem.

3.1.2 Percentage improved

As this criterion is concerned with whether or not a translation performs faster, the reference is implicit through the figures below.

Table 3.3: March_dl, top 3 percentage improved

1. PRPYP2 (44.6 %)
2. PRS (42.6 %)
3. PRPY – PRSP (41.9 %)

Table 3.4: MiniSAT, top 3 percentage improved

1. PRS (35.1 %)
2. PRPY – PRPYP2 (33.1 %)
3. PRSP (31.1 %)

From tables 3.3 and 3.4, it becomes clear that for this criterion only 4 translations actually mattered. Of these 4 methods it seems PRS and PRPYP2 collectively perform best, with PRSP following closely. However, the potential improvement is greatest amongst the times recorded by instances fed to March_dl. This information can be helpful in research where overall performance improvement is important.

3.1.3 Average improvement

The average improvement is also implicitly related to the reference copy.

Table 3.5: March_dl, top 3 average improvement

1. PRPY (48.0 %)
2. PRS (46.7 %)
3. PRSP (46.4 %)

Again PRSP scores high on both solvers yet CH appears in a top 3 here for the first time. It must be noted that PRPY (rank 4) scored slightly below CH, even though it remains odd that CH would even show up here as

Table 3.6: MiniSAT, top 3 average improvement

1. PRPYP1 (65.1 %)
2. PRSP (63.6 %)
3. CH (62.6 %)

it scored very poorly on all other criteria. The consequences of these data could be of particular interest to research where potential speed increase is considered crucial.

3.1.4 Total overview

In tables 3.7 and 3.8 the scores of all translations on each criterion are listed by March_dl and MiniSAT respectively.

Table 3.7: March_dl; Percentage Timeouts, Improved and Average Improvement

	ref	ch	py	pyp1	pyp2	prpy	prpyp1	prpyp2	prs	prsp	s	sp
% timeouts	0.7	83.1	67.6	61.5	65.5	20.9	16.2	19.6	19.6	28.4	65.5	67.6
% improved		4.1	10.8	10.8	13.5	41.9	40.5	44.6	42.6	41.9	10.1	10.8
% avg. improvement		27.7	22.2	24.5	12.1	48.0	43.1	44.0	46.7	44.4	13.0	28.0

Table 3.8: Minisat; Percentage Timeouts, Improved and Average Improvement

	ref	ch	py	pyp1	pyp2	prpy	prpyp1	prpyp2	prs	prsp	s	sp
% timeouts	8.1	16.2	9.4	6.8	7.4	2.0	1.4	2.0	3.4	3.4	10.1	10.1
% improved		10.8	15.5	22.3	20.3	33.1	32.4	33.1	35.1	31.1	16.9	14.2
% avg. improvement		62.6	54.2	61.1	59.1	62.4	65.1	60.8	57.8	63.6	47.0	72.4

Chapter 4

Conclusions

Almost all translations performing best under each criterion, involve preprocessing. Such translations show the lowest percentage of timeouts, attain an increase in performance most often and, furthermore, this increase is on average the highest. Because of these findings, it may be best to apply preprocessing by itself and then feed the translated copy to a solver.

There is not one true winner here, the performance of a translation is greatly influenced by the instance it is applied to and the solver used to process. Hence the choice of translation depends on the desired effect.

It should be noted that no translation was able to attain a level of 50% increase in performance. This is due to the fact that current solvers are optimized and may already apply some form of translation of their own. Considering this fact, the first choice should be whether to actually apply a translation or not.

There are slight differences between the performance of both respective solvers. Using March_dl a higher number of increased performance was measured, however the average increase was lower than that of MiniSAT. MiniSAT also showed drastic decrease in the number of timeouts with respect to the reference copy. The number of timeouts is much higher after translation when solved by March_dl, even though this solver showed only 0.7% timeouts when processing the reference copies.

Appendices

Appendix A

Raw data for March_dl

A.1 Satisfiable Instances

Table A.1: Raw data for March_dl; Satisfiable Instances

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
clqcolor-14-09-09-1244	0.16	0.56	0.17	0.16	0.15	0.17	0.16	0.14	0.14	0.14	0.14	0.14
clqcolor-16-11-11-1245	0.36	118.39	0.36	21.86	0.4	0.36	21.91	0.39	0.34	0.37	0.35	0.37
clqcolor-20-15-15-1246	1.75	TO	1.65	1.68	1.72	1.66	1.71	1.69	1.54	1.57	1.53	1.56
clqcolor-30-20-20-1248	TO	TO	629.28	9.49	9.81	632.9	9.53	9.8	TO	9.08	TO	9.07
fclqcolor-25-18-18-1271	5.48	TO	5.22	5.32	5.32	5.2	5.3	5.31	5.14	5.11	5.1	5.08
fclqcolor-30-20-20-1272	11.46	TO	11.03	11.02	11.04	11.04	11.06	11.07	11.09	10.38	11.07	10.41
fphp-060-060-1211	7.4	5.19	7.9	8	7.17	7.93	8.02	7.22	12.73	7.59	12.74	7.64
fphp-070-070-1212	12.96	9.48	13.67	13.8	12.45	13.69	13.81	12.49	23.9	18.02	23.91	17.86
gensys-brn001-2743	5.71	TO	896.59	TO	TO	TO	TO	TO	407.59	TO	TO	TO
gensys-brn001-3127	12.18	55.61	TO	TO	TO	2.74	3.29	8.41	2.52	3.14	66.79	288.19
gensys-brn001-3420	787.32	TO	TO	424.21	TO	67.62	75.07	69.43	67.96	72.86	TO	TO
gensys-brn001-3934	154.2	TO	TO	TO	TO	63.13	TO	22.65	66.7	37.26	TO	TO
gensys-brn002-2679	5.82	TO	TO	802.25	95.96	60.19	15.07	71.32	48.76	TO	TO	TO
gensys-brn002-2746	35.01	TO	TO	TO	85.25	3.03	3.54	3.67	2.35	3.2	TO	289.82
gensys-brn002-3421	44.02	TO	TO	438.96	TO	49.96	55.31	52.76	51.53	54.86	TO	TO
gensys-brn002-3935	176.01	TO	TO	TO	TO	64	30.13	21.88	94.62	26.45	TO	TO
gensys-brn003-2680	108.5	TO	TO	619.26	TO	407.74	TO	TO	32.71	TO	TO	TO
gensys-brn003-2747	35.99	TO	29.77	TO	70.48	16.29	21.21	14.6	16.44	14.44	65.33	268.97
gensys-brn003-3422	34.21	TO	TO	TO	TO	277.13	492.61	428.73	273.16	462	TO	TO
gensys-brn003-3668	55.2	TO	TO	TO	TO	TO	62.25	TO	TO	TO	TO	TO
gensys-brn004-2681	35.49	TO	TO	731.43	TO	TO	TO	TO	TO	TO	TO	979.82
gensys-brn004-2748	11.52	TO	40.91	TO	89.8	3.33	3.31	3.13	2.9	2.89	TO	626.13
gensys-brn004-3423	414.24	TO	TO	TO	TO	190.52	232	222.97	227.23	371.29	TO	TO
gensys-brn004-3669	38.91	TO	TO	TO	TO	TO	985.27	TO	TO	TO	TO	TO
gensys-brn005-2682	59.51	TO	TO	537.94	TO	TO	TO	TO	722.22	TO	TO	TO
gensys-brn005-2749	2.95	TO	31.01	35.35	59.79	0.91	0.99	0.92	0.87	0.84	67.26	602.57

Continued on next page

Table A.1 – continued from previous page

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
gensys-brn005-3424	1051.98	TO	TO	TO	TO	149.63	215.99	140.29	150.46	186.27	TO	TO
gensys-brn005-3670	17.9	TO	TO	TO	TO	TO	328.7	TO	59.81	44.75	TO	TO
gensys-brn006-2683	58.53	TO	TO	TO	TO	332.44	202.59	TO	519.87	TO	TO	703.08
gensys-brn006-2750	11.91	TO	30.13	33.76	62.5	1.35	11.42	2.81	1.21	73.15	128.16	271.9
gensys-brn006-3425	599.68	TO	TO	TO	TO	243.33	269.48	299.57	252.93	516.25	TO	TO
gensys-brn006-3671	18.34	TO	TO	TO	TO	67.84	234.32	22.87	107.02	22.57	TO	TO
gensys-brn007-2751	11.24	58.26	33.37	39.85	70.15	3.44	7.7	6.2	3.62	6.89	70.72	507.59
gensys-brn007-3426	1197.06	TO	TO	TO	TO	366.99	669.28	445.85	489.93	627.01	TO	TO
gensys-brn007-3672	41.82	TO	TO	TO	TO	82.92	108.03	120.17	TO	29.57	TO	TO
gensys-brn008-2752	10.43	63.88	TO	41.6	107.02	6.69	3.06	2.88	3.08	2.92	78.51	458.41
gensys-brn008-3427	429.98	TO	TO	TO	TO	91.67	100.39	104.12	90.13	115.2	TO	TO
gensys-brn008-3673	23.16	TO	TO	TO	TO	184.6	129.14	25.04	62.27	37.54	TO	TO
gensys-brn009-2686	7.16	TO	TO	TO	TO	TO	65.63	TO	TO	TO	TO	TO
gensys-brn009-2753	11.35	TO	TO	44.99	57.15	3.42	6.9	5.61	3.45	6.86	TO	440.27
gensys-brn009-3428	189.8	TO	TO	TO	TO	132.98	404.87	59.4	93.18	295.54	TO	TO
gensys-brn009-3674	39.82	TO	TO	TO	TO	323.39	44.48	29.3	91.52	35.79	TO	TO
gensys-brn100-2844	56.88	TO	TO	59.63	TO	7.58	20.23	9.97	7.21	18.11	375.24	418.44
gensys-brn100-3765	187.52	TO	TO	TO	TO	TO	TO	928.67	TO	TO	TO	TO
gensys-ukn001-3235	30.74	TO	TO	TO	TO	6.39	5.84	4.98	11.54	5.55	TO	TO
gensys-ukn001-3500	233.33	TO	TO	TO	TO	92.11	121.69	134.1	92.66	113.63	TO	TO
gensys-ukn001-3841	72.39	TO	TO	TO	TO	TO	121.22	1145.04	TO	TO	TO	TO
gensys-ukn002-3345	25.08	TO	239.48	162.89	TO	14.56	20.43	8.26	8.67	11.46	TO	TO
gensys-ukn002-3501	334.58	TO	TO	TO	TO	218.03	274.57	268.53	239.43	277.3	TO	TO
gensys-ukn003-3582	323.12	TO	TO	TO	TO	28.47	30.8	26.54	28.47	28.86	TO	TO
gensys-ukn004-3583	232.62	TO	TO	TO	TO	94.46	134.16	110.39	96.4	155.69	TO	TO
gensys-ukn005-3845	34.41	TO	TO	TO	TO	326.69	201.59	78.15	TO	TO	TO	TO
gensys-ukn009-3352	84.57	TO	404.78	TO	TO	TO	49.41	418.69	TO	90.38	440.71	TO

Continued on next page

Table A.1 – continued from previous page

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
grid-pbl-0060-1333	1.08	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
grid-pbl-0070-1334	2.32	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
grid-pbl-0080-1335	3.49	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
grid-pbl-0090-1336	9.02	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
grid-pbl-0100-1337	8.59	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
grid-pbl-0150-1338	49.56	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
grid-pbl-0200-1339	271.05	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
grid-pbl-0250-1340	245.44	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
iso-brn001-2741	22.51	TO	TO	TO	TO	892.26	TO	1003.05	256.78	48.16	TO	TO
iso-brn002-2696	20.82	TO	TO	TO	TO	TO	807.76	TO	233.56	TO	TO	TO
iso-brn003-2697	11.26	TO	TO	999.25	TO	666.06	39.86	TO	53.19	TO	TO	971.56
iso-brn003-3503	3.71	TO	TO	817.32	194.09	0.54	0.49	0.57	0.54	0.56	636.43	TO
iso-brn004-2698	3.74	TO	TO	TO	TO	20.52	34.16	11.25	63.41	42.66	TO	1089.46
iso-brn004-3504	3.75	TO	TO	TO	TO	1.73	1.58	1.56	1.78	1.65	772.71	TO
iso-brn005-2699	10.26	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
iso-brn005-3505	4.89	TO	TO	TO	TO	10.74	13.29	1.99	22.91	TO	808.67	TO
iso-brn006-2700	55.03	TO	TO	TO	TO	61.82	828.66	775.1	TO	TO	TO	TO
iso-brn006-3506	4.52	TO	1064.94	TO	TO	2.26	1.87	1.96	2.2	1.82	809.96	TO
iso-brn007-2701	3.98	TO	TO	TO	TO	52.58	85.54	47.66	52.69	74.48	TO	TO
iso-brn007-3507	13.01	TO	TO	TO	TO	28.47	12.29	8.95	28.32	12.83	TO	TO
iso-brn008-2702	12	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
iso-brn008-3508	6.13	TO	TO	TO	TO	2.56	2.46	2.59	2.45	2.77	TO	TO
iso-brn009-2703	5.12	TO	TO	TO	TO	204.92	150.21	811.22	85.59	TO	TO	TO
iso-brn009-3509	6.03	TO	TO	TO	TO	200.04	12.8	45.08	73.31	TO	TO	TO
iso-ukn001-3581	6.02	TO	TO	480.85	217.64	1.58	1.53	1.71	1.58	1.68	748.02	TO
iso-ukn002-3625	3.96	TO	1007.43	484.45	168.23	1.87	1.71	1.89	1.86	1.82	706.8	TO
iso-ukn003-3384	1.02	TO	TO	20.7	5.97	0.65	0.7	0.99	0.63	0.78	TO	14.32

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Table A.1 – continued from previous page

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
iso-ukn003-3626	3.25	TO	776.28	418.87	165.89	0.68	0.62	0.76	0.66	0.8	524.46	TO
iso-ukn004-3385	0.65	24.79	21.48	16.93	10.87	0.84	0.83	0.86	0.84	1.14	21.34	17.73
iso-ukn005-3628	0.27	TO	6.89	48.16	25.24	0.44	0.6	0.6	0.46	0.7	10.86	79.46
iso-ukn006-3387	0.47	5.15	5.55	3.21	2.88	1.23	0.92	0.88	1.21	1.04	6	4.07
iso-ukn009-3632	0.94	32.49	10.93	15.68	17.96	0.78	1.42	1.25	0.79	1.28	13.17	52.23
logistics-rotate-06t6-1130	23.53	TO	10.33	10.42	11.54	10.33	10.43	11.56	104.54	227.61	104.98	225.78
logistics-rotate-07t6-1131	20.19	TO	TO	TO	56.28	TO	TO	56.37	TO	TO	TO	TO
mod2c-rand3bip-sat-150-1-2383	70.05	TO	TO	TO	550.59	36.55	35.92	36.41	36.17	36.37	TO	TO
mod2c-rand3bip-sat-150-2-2384	1.37	TO	TO	TO	TO	23.65	23.73	23.63	23.7	25.56	TO	TO
mod2c-rand3bip-sat-150-3-2385	11.9	TO	TO	TO	TO	19.71	19.81	19.63	19.91	19.67	TO	TO
mod2c-rand3bip-sat-160-1-2398	10.94	TO	TO	TO	TO	55.64	55.67	55.78	55.65	55.54	TO	TO
mod2c-rand3bip-sat-160-2-2399	46.99	TO	TO	TO	TO	50.4	50.13	50.16	50.42	50.41	TO	TO
mod2c-rand3bip-sat-160-3-2400	69.76	TO	TO	TO	TO	118.48	118.61	118.86	119.37	118.28	TO	TO
mod2c-rand3bip-sat-170-1-2413	67.19	TO	TO	TO	TO	61.06	61.15	61.15	61.13	61.12	TO	TO
mod2c-rand3bip-sat-170-2-2414	61.66	TO	TO	TO	TO	59.02	59.21	58.54	58.75	58.69	TO	TO
mod2c-rand3bip-sat-170-3-2415	449.66	TO	TO	TO	TO	421.14	425.25	425.41	426.05	424.94	TO	TO
mod2c-rand3bip-sat-180-1-2428	75.38	TO	TO	TO	TO	317.88	319.83	319.52	319.94	318.76	TO	TO
mod2c-rand3bip-sat-180-2-2429	4.98	TO	TO	TO	TO	13.37	13.33	13.39	13.42	13.4	TO	TO
mod2c-rand3bip-sat-180-3-2430	232.7	TO	TO	TO	TO	128.59	127.63	127.5	127.52	127.1	TO	TO
mod2c-rand3bip-sat-190-1-2443	101.1	TO	TO	TO	TO	91.53	91.87	91.6	91.57	91.57	TO	TO
mod2c-rand3bip-sat-190-2-2444	29.89	TO	TO	TO	TO	188.53	188.6	189.4	188.5	188.09	TO	TO
mod2c-rand3bip-sat-190-3-2445	901.51	TO	TO	TO	TO	691.37	691.27	688.19	689.73	689.56	TO	TO
mod2c-rand3bip-sat-210-1-2473	260.58	TO	TO	TO	TO	140.16	139.9	139.99	139.59	140.17	TO	TO
mod2c-rand3bip-sat-210-2-2474	868.93	TO	TO	TO	TO	1190.66	1193.55	1186.86	1182.44	1191.95	TO	TO
pbl-00100-1317	2.25	TO	TO	TO	55.58	1.16	1.16	1.18	1.16	1.21	TO	TO
php-012-012-1158	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
php-014-014-1159	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01

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Table A.1 – continued from previous page

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
php-016-016-1160	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03
php-018-018-1161	0.03	0.03	0.04	0.05	0.04	0.03	0.05	0.04	0.02	0.04	0.02	0.04

A.2 Unsatisfiable Instances

Table A.2: Raw data for March_dl; Unsatisfiable Instances

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
clqcolor-08-05-06-1249	201.38	148.22	266.85	159.48	201.19	267.43	160.54	202.66	252.11	111.83	249.52	111.43
connm-ue-csp-sat-547	625.63	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
dead-dnd003-3109	1082.89	TO	TO	TO	TO	TO	536.88	522.63	233.69	601.2	TO	TO
fclqcolor-08-05-06-1273	35.87	983.26	34.55	34.47	34.86	34.31	34.54	35.16	33.57	34.84	33.57	34.83
fclqcolor-08-06-07-1281	438.47	605.12	427.63	427.4	438.07	427.31	426.22	431.49	395.75	442.59	395.86	443.57
fphp-010-009-1227	5.24	6.43	5.15	5.12	5.1	5.12	5.12	5.11	4.84	4.68	4.82	4.67
fphp-012-010-1214	70.24	71.92	74.22	73.64	69.67	73.9	73.7	69.37	74.35	65.01	73.91	64.99
fphp-012-011-1228	653.98	839.58	679.1	680.29	648.15	678.06	681.89	647.72	655.05	616.37	654.02	614.08
gensys-icl001-2926	120.3	TO	698	645.03	TO	141.51	156.88	134.29	144.63	141.8	618.02	TO
gensys-icl002-3128	58.25	TO	139.41	158.86	TO	48.19	47.62	59.16	76.88	65.15	137.86	TO
gensys-icl004-3130	95.47	583.6	46.47	46.32	1030.91	256.47	284.12	269.92	303.35	229.27	44.93	TO
gensys-ukn005-3584	892.35	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
gensys-ukn006-3585	221.72	TO	TO	TO	TO	539.53	562.3	481.27	472.04	470.45	TO	TO
gensys-ukn007-3586	3	290.06	83.62	348.02	TO	16.39	20.74	20.72	16.37	20.64	101.73	TO
gensys-ukn008-3587	58.84	TO	313.15	339.38	TO	46.15	55.55	54.08	47.32	54.65	392.88	TO
grid-pbl-0060-1342	0.85	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
gt-012-1301	234.69	TO	TO	539.43	183.82	TO	540.05	186.33	TO	0.16	TO	0.16
iso-icl001-2712	6.41	TO	TO	TO	TO	114.64	257.6	243.05	140.65	TO	TO	TO
iso-icl002-2727	14.03	TO	TO	TO	TO	47.42	128.78	260.62	87.45	251.01	TO	TO
iso-icl003-2728	22.58	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
iso-icl004-2729	69.97	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
iso-icl005-2730	94.15	TO	TO	TO	TO	194.42	580.01	854.36	83.45	TO	TO	TO
iso-icl006-2731	38.12	TO	TO	TO	TO	362.03	418.73	787.76	243.21	792.42	TO	TO
iso-icl007-2732	14.07	TO	TO	TO	TO	790.95	1000.92	985.93	949.72	1048.37	TO	TO
iso-icl008-2733	17.06	TO	TO	TO	TO	145.24	217.07	155.99	153.35	TO	TO	TO
iso-icl009-2734	14.04	TO	TO	TO	TO	614.91	955.15	TO	630.64	TO	TO	TO

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Table A.2 – continued from previous page

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
iso-icl100-3334	1.12	TO	3.38	4.79	6.84	1.83	2.28	3.08	1.99	4.23	3.29	16.4
iso-ukn001-2740	22.79	TO	TO	TO	TO	314.6	316.78	512.83	265.95	TO	TO	TO
iso-ukn002-2676	43.24	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
iso-ukn003-2677	33.99	TO	TO	TO	TO	TO	464.31	TO	1138.29	TO	TO	TO
iso-ukn004-2739	22.47	TO	TO	TO	TO	285.58	472.92	417.91	209.54	TO	TO	TO
iso-ukn005-3386	2.95	TO	5.49	6.54	11.54	1.03	0.95	1	1.02	1.03	5.61	19.31
iso-ukn007-3388	1.41	TO	3.87	6.08	9.84	1.23	2.37	2.46	1.28	1.9	4.05	38.02
iso-ukn008-3389	1.38	TO	5.92	11.33	13.7	2.4	4.14	4.75	2.38	4.91	6.06	77.24
iso-ukn009-3390	0.8	TO	3.49	7.02	7.57	0.95	1.51	1.52	0.99	1.57	3.1	41.1
logistics-rotate-06t5-1136	23.49	26.44	20.82	20.39	22.58	20.67	20.47	22.6	23.4	17.62	23.46	17.68
logistics-rotate-07t5-1137	444.53	TO	777.86	530.4	537.59	767.51	528.14	539.65	833.24	515.59	829.85	518.43
php-010-009-1185	6.9	10.16	6.98	5.93	6.89	7.02	5.93	6.83	7.21	5.34	7.22	5.34
php-012-010-1172	100.71	138.76	92.89	78.04	105.49	93.02	77.76	105.53	93.09	68.38	92.89	68.18

Appendix B

Raw data for Minisat

B.1 Satisfiable Instances

Table B.1: Raw data for Minisat; Satisfiable Instances

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
clqcolor-14-09-09-1244	0.46	0	4.43	9.57	0.18	4.4	9.54	0.18	4.45	37.57	4.44	37.67
clqcolor-16-11-11-1245	8.08	0.01	15.61	77.28	15.15	15.55	77.09	15.09	0.01	0.01	0.01	0.01
clqcolor-20-15-15-1246	TO	TO	278.84	221.85	TO	278.4	223.59	TO	TO	TO	TO	TO
clqcolor-30-20-20-1248	TO	0.15	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO
fclqcolor-25-18-18-1271	0.1	0.1	0.1	0.1	0.07	0.09	0.1	0.08	0.1	0.11	0.1	0.11
fclqcolor-30-20-20-1272	0.18	0.17	0.16	0.14	0.15	0.17	0.15	0.16	0.17	0.15	0.16	0.15
fphp-060-060-1211	0.14	0.16	0.16	0.18	0.15	0.16	0.17	0.16	0.15	0.14	0.15	0.14
fphp-070-070-1212	0.24	0.26	0.26	0.28	0.26	0.26	0.28	0.25	0.24	0.23	0.23	0.25
gensys-brn001-2743	1.56	24.79	6.17	18.35	36.93	12.25	2.18	5.02	3.78	11.73	1.83	33.87
gensys-brn001-3127	0.02	0.19	0.05	0.06	0.18	0.06	0.03	0.03	0.04	0.04	0.04	0.31
gensys-brn001-3420	0.06	9.83	0.3	0.71	1.79	0.08	0.08	0.09	0.08	0.08	0.3	1.96
gensys-brn001-3934	15.43	335.62	29.77	75.62	54.36	58.4	112.08	124.78	75.51	95	21.4	236.75
gensys-brn002-2679	0.25	21.39	11.89	15.59	57.15	6.13	25.09	10.64	12.01	17.78	8.3	46.87
gensys-brn002-2746	0.02	0.22	0.06	0.09	0.17	0.01	0.02	0.03	0.02	0.02	0.06	0.18
gensys-brn002-3421	0.06	10.51	0.29	0.61	0.89	0.06	0.07	0.07	0.05	0.07	0.31	1.3
gensys-brn002-3935	40.83	393.18	110.97	67.52	109.14	76.9	134.29	158.78	76.03	133.66	53.96	73.69
gensys-brn003-2680	1.09	28.86	4.57	27.29	50.8	25.89	35.48	51.41	18.49	19.54	2.84	137.5
gensys-brn003-2747	0.02	0.47	0.06	0.08	0.11	0.05	0.05	0.06	0.03	0.03	0.05	0.16
gensys-brn003-3422	0.08	103.63	0.5	26.6	2.54	0.14	0.16	0.18	0.14	0.15	0.47	1.67
gensys-brn003-3668	53.32	254.18	138.67	66.44	309.04	160.55	70.75	201.75	56.08	89.42	154.73	251.34
gensys-brn004-2681	32.81	29.96	15.35	457.09	133.26	22.25	80.51	212.45	10.77	12.38	89.09	TO
gensys-brn004-2748	0.05	1.31	0.17	0.04	0.23	0.11	0.16	0.04	0.03	0.15	0.05	0.47
gensys-brn004-3423	0.16	109.66	1.52	54.35	10.14	1.04	1.23	1.05	0.76	1.33	0.88	4.63
gensys-brn004-3669	200.27	996.84	343.32	107.36	725.19	518.73	382.42	485.06	272.57	471.03	256.49	TO
gensys-brn005-2682	6.1	19.74	4.41	143.43	26.71	72.72	72.54	42.21	51.94	55.47	11.78	166.27
gensys-brn005-2749	0.04	0.73	0.06	0.06	0.46	0.04	0.08	0.06	0.1	0.02	0.13	0.34

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Table B.1 – continued from previous page

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
gensys-brn005-3424	0.36	159.55	1.91	63.26	10.87	1.14	0.94	1.14	1.14	1.38	0.86	3.6
gensys-brn005-3670	145.31	TO	618.2	379.39	TO	109.99	200.74	212.55	186.22	249.96	422.59	937.97
gensys-brn006-2683	2.32	24.13	5.32	11.94	62.08	64.12	16.93	36.35	32.57	97.13	25.02	53.06
gensys-brn006-2750	0.02	0.3	0.04	0.11	0.18	0.02	0.06	0.04	0.03	0.03	0.04	0.19
gensys-brn006-3425	0.24	163.22	2.65	49.2	9.64	1.15	0.71	0.94	0.95	0.93	1.41	4.22
gensys-brn006-3671	51.48	209.12	33.6	82.99	154.99	92.34	78.32	112.03	41.93	97.89	45.64	243.64
gensys-brn007-2751	0.02	0.38	0.06	0.1	0.21	0.06	0.08	0.05	0.04	0.07	0.05	0.21
gensys-brn007-3426	0.49	280.36	2.16	120.22	34.42	3.63	4.85	5.28	2.87	5.54	2.52	29.68
gensys-brn007-3672	49.91	620.9	52.51	73.65	115.03	95.03	249.44	133.19	53.96	135.36	34.09	273.43
gensys-brn008-2752	0.02	1.59	0.09	0.07	0.43	0.02	0.02	0.04	0.02	0.04	0.06	0.14
gensys-brn008-3427	0.18	206.56	2.12	58.71	8.39	1.29	1.63	1.12	1.35	1.43	1.01	4.89
gensys-brn008-3673	20.95	562.24	41.75	120.42	190.74	144.53	80.21	188.12	49.2	102.05	92.27	287.95
gensys-brn009-2686	0.91	23.74	10.98	30.81	43.78	10.04	31.83	29.75	25.73	23.63	20.43	13.78
gensys-brn009-2753	0.03	1.49	0.07	0.16	0.22	0.04	0.04	0.04	0.04	0.06	0.05	0.15
gensys-brn009-3428	0.56	307.13	7.71	179.01	13.5	4.15	5.62	3.62	3.13	2.39	2.22	12.52
gensys-brn009-3674	41.65	259.85	103.93	82.1	511.06	58.81	97.95	207.39	149.1	192.18	35.49	193.62
gensys-brn100-2844	0.02	2.48	0.22	0.25	1.5	0.26	0.64	0.24	0.36	0.94	0.17	0.4
gensys-brn100-3765	162.38	397.72	133.75	273.17	617.78	268.46	342.46	180.68	151.31	239.52	264.93	713.07
gensys-ukn001-3235	0.08	8.31	0.19	0.62	3.16	0.17	0.18	0.64	0.12	0.22	0.42	1.2
gensys-ukn001-3500	0.08	175.56	0.69	39.31	2.07	0.18	0.12	0.13	0.16	0.19	0.76	1.9
gensys-ukn001-3841	449.21	624.3	575.68	373.13	252.34	366.13	218.89	273.61	128.2	189.8	282.56	613.18
gensys-ukn002-3345	0.22	9.44	0.35	2.96	2.16	0.58	0.91	0.69	0.56	2.32	0.32	0.87
gensys-ukn002-3501	0.1	171.88	1.07	40.07	3.86	0.4	0.56	0.75	0.64	1.09	1.02	3.58
gensys-ukn003-3582	0.1	129.51	0.61	23	2.64	0.07	0.08	0.08	0.08	0.07	0.39	0.95
gensys-ukn004-3583	0.12	16.89	0.53	1.72	3.51	0.27	0.16	0.15	0.12	0.13	0.4	1.86
gensys-ukn005-3845	146.46	411.55	137.12	601.43	776.48	73.87	322.86	190.35	107.61	86	391.39	283.91
gensys-ukn009-3352	0.45	20.92	0.62	5.43	15.29	0.47	0.83	1.82	0.4	0.51	0.45	8.79

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Table B.1 – continued from previous page

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
grid-pbl-0060-1333	12.62	384.99	2.2	2.74	2.75	0.93	0.94	0.94	0.93	0.94	2.19	2.74
grid-pbl-0070-1334	34.03	TO	15.48	2.88	2.87	1.62	1.6	1.61	1.61	1.6	15.5	2.9
grid-pbl-0080-1335	57.59	TO	34.5	7.61	7.63	3.18	3.6	3.6	3.18	3.62	34.57	7.63
grid-pbl-0090-1336	41.05	TO	52.7	5.27	5.28	3.21	3.18	3.18	3.22	3.18	52.88	5.28
grid-pbl-0100-1337	71.83	TO	777.35	22.59	22.46	9.3	9.67	9.68	9.26	9.68	777.08	22.43
grid-pbl-0150-1338	TO	TO	TO	112.85	112.82	44.53	46.11	45.83	44.45	45.82	TO	112.88
grid-pbl-0200-1339	TO	TO	TO	223.47	223.54	92.51	88.11	87.94	92.29	88.15	TO	222.75
grid-pbl-0250-1340	TO	TO	TO	TO	TO	359.36	344.58	343.49	357.34	343.85	TO	TO
iso-brn001-2741	0.73	44.91	6.23	10.3	23.55	5.73	7.31	3.78	5.54	9.44	3.26	20.56
iso-brn002-2696	0.42	34.62	4.48	11.47	12.03	1.91	4.9	11.16	4.39	10.39	4.8	13.7
iso-brn003-2697	1.43	19.43	2.34	4.19	3.48	2.15	2.92	4.24	3.07	5.59	1.76	6.9
iso-brn003-3503	0.03	4.58	0.1	12.88	0.18	0.01	0.01	0.01	0.01	0.01	0.08	0.14
iso-brn004-2698	0.34	35.51	9.02	5.25	8.41	0.36	6.53	0.92	5.24	7.34	4.9	24.72
iso-brn004-3504	0.06	27.4	0.41	9.71	2.09	0.09	0.12	0.12	0.11	0.16	0.41	0.72
iso-brn005-2699	0.85	54.27	10.37	9.26	15.17	7.3	2.7	6.94	3.44	5	17.37	12.18
iso-brn005-3505	0.1	24.36	0.61	5.86	2.15	0.11	0.16	0.16	0.18	0.21	0.66	3.34
iso-brn006-2700	1.52	42.4	29.84	27.21	33.47	6.64	15.23	8.66	5.49	9.78	7.3	48.14
iso-brn006-3506	0.06	19.37	0.44	6.38	2.35	0.14	0.18	0.14	0.1	0.19	0.48	1.17
iso-brn007-2701	0.82	42.92	1.16	7.78	9.34	1.74	4.84	0.39	1.56	3.16	4.87	57.12
iso-brn007-3507	0.15	57.4	1.41	15.67	4.07	0.62	1.66	2.89	0.89	1.26	1.62	7.88
iso-brn008-2702	1.02	58.17	13.69	12.95	19.84	5.49	9.8	12.78	12.56	12.82	5.32	39.63
iso-brn008-3508	0.06	24.63	0.4	13.82	0.96	0.16	0.22	0.28	0.2	0.18	0.46	1.18
iso-brn009-2703	0.53	38.13	2.71	4.14	16.15	6.28	3.71	6.33	7.59	11.72	4.24	9.21
iso-brn009-3509	0.08	52.21	1.58	13.91	2.87	0.44	0.42	0.84	0.45	0.62	0.74	4.43
iso-ukn001-3581	0.04	15.34	0.15	12.66	0.54	0.04	0.03	0.02	0.02	0.03	0.12	0.23
iso-ukn002-3625	0.05	34.91	0.5	8.54	1.25	0.13	0.2	0.22	0.16	0.12	0.45	0.24
iso-ukn003-3384	0.1	2.5	0.31	0.3	0.31	0.11	0.12	0.2	0.14	0.22	0.09	0.24

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Table B.1 – continued from previous page

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
iso-ukn003-3626	0.04	5.48	0.1	7.93	0.18	0.02	0	0.02	0	0.02	0.07	0.14
iso-ukn004-3385	0.04	3.34	0.07	0.2	0.12	0.11	0.11	0.09	0.08	0.08	0.06	0.18
iso-ukn005-3628	0.02	1.12	0.05	0.38	0.12	0.02	0.02	0.02	0.01	0.01	0.03	0.08
iso-ukn006-3387	0.02	0.75	0.03	0.06	0.04	0.02	0.04	0.04	0.02	0.03	0.02	0.03
iso-ukn009-3632	0.03	2.38	0.08	0.44	0.14	0.07	0.07	0.05	0.08	0.05	0.08	0.13
logistics-rotate-06t6-1130	0.69	0.84	1.34	0.27	0.51	1.33	0.27	0.52	4.45	0.32	4.43	0.33
logistics-rotate-07t6-1131	2.79	2.56	8.11	1.77	2.56	7.99	1.75	2.53	1.85	1.26	1.84	1.25
mod2c-rand3bip-sat-150-1-2383	12.7	12.94	86.34	11.56	23.55	14.85	14.95	14.98	14.98	14.95	1.23	20.47
mod2c-rand3bip-sat-150-2-2384	2.95	54.42	13.46	38.05	42.28	1.4	1.4	1.36	1.37	1.36	62.82	76.63
mod2c-rand3bip-sat-150-3-2385	7.79	292.19	108.29	24.8	112.12	3.77	3.73	3.76	3.74	3.74	47.82	45.73
mod2c-rand3bip-sat-160-1-2398	28.53	145.61	53.34	28.28	141.17	26.29	26.24	26.26	26.22	26.26	190.04	38.45
mod2c-rand3bip-sat-160-2-2399	98.61	TO	150.47	277.75	142.36	60.54	60.62	60.96	60.4	60.67	556.35	229.99
mod2c-rand3bip-sat-160-3-2400	76.42	282.21	72.13	375.88	153.44	59.2	59.27	59.21	59.7	59.19	705.58	333.52
mod2c-rand3bip-sat-170-1-2413	145.02	TO	567.82	724.54	510.9	67.28	67.12	67.24	66.94	67.46	546.32	TO
mod2c-rand3bip-sat-170-2-2414	97.72	TO	TO	TO	755.31	202.31	201.81	201.96	201.51	201.15	TO	695.62
mod2c-rand3bip-sat-170-3-2415	480.62	TO	TO	TO	670.01	219.81	219.91	219.78	220.04	219.13	TO	1093.65
mod2c-rand3bip-sat-180-1-2428	677.94	TO	TO	209.8	587.63	232.6	233.09	232.8	233.86	232.65	TO	TO
mod2c-rand3bip-sat-180-2-2429	1143.36	TO	TO	TO	669.11	325.28	326.15	324.92	324.73	325.34	618.29	TO
mod2c-rand3bip-sat-180-3-2430	145.6	310.81	385.41	356.14	152.65	13.87	13.9	13.88	13.86	13.85	353.09	343.49
mod2c-rand3bip-sat-190-1-2443	434.88	794.13	1032.76	249.06	338.13	65.74	65.78	65.92	65.66	65.82	1108.01	207.65
mod2c-rand3bip-sat-190-2-2444	416.02	TO	TO	TO	TO	618.23	618.94	618.88	619.76	618.76	TO	1051.7
mod2c-rand3bip-sat-190-3-2445	21.54	TO	TO	TO	TO	142.1	141.93	141.89	142.02	141.67	TO	TO
mod2c-rand3bip-sat-210-1-2473	TO	725.11	751.47	108.77	288.55	496.41	495.86	495.97	497.55	495.91	580.44	TO
mod2c-rand3bip-sat-210-2-2474	TO	TO	TO	TO	TO	714.93	714.36	717.71	716.54	717.7	TO	TO
pbl-00100-1317	0.04	153.59	0.65	2.34	1.78	0.01	0.02	0.01	0.02	0.03	0.36	0.72
php-012-012-1158	232.9	0	0.04	0	0.02	0.04	0	0.02	0	0	0	0
php-014-014-1159	TO	TO	0.33	2.95	13.34	0.33	2.96	13.4	TO	0	TO	0

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Table B.1 – continued from previous page

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
php-016-016-1160	TO	0	232.31	2.55	0.33	232.18	2.55	0.34	0	0	0	0
php-018-018-1161	TO	TO	TO	0	TO	TO	0	TO	TO	TO	TO	TO

B.2 Unsatisfiable Instances

Table B.2: Raw data for Minisat; Unsatisfiable Instances

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
clqcolor-08-05-06-1249	63.94	22.53	40.07	8.85	8.21	40.07	8.84	8.22	15.83	11.11	15.83	11.08
connm-ue-csp-sat-547	1106.54	609.97	381.1	404.25	405.27	380.54	404.99	404.58	381.31	404.57	381.42	404.89
dead-dnd003-3109	TO	TO	TO	TO	TO	TO	TO	754.2	TO	TO	TO	TO
fclqcolor-08-05-06-1273	64.74	20.37	9.02	14.79	24.73	9	14.81	24.63	53.87	65.17	53.74	65.4
fclqcolor-08-06-07-1281	10.35	3.54	5.82	6.58	7.98	5.83	6.58	7.96	5.46	14.01	5.44	14.03
fphp-010-009-1227	2.82	5.36	3.08	3.32	3.01	3.08	3.32	3.01	4.29	3.65	4.29	3.66
fphp-012-010-1214	148.67	95.67	73.35	80.22	74.24	73.33	80.15	74.52	105.92	93.15	105.97	92.8
fphp-012-011-1228	938.87	TO	551.41	657.38	629.85	550.33	657.87	631.73	755.42	TO	753.65	TO
gensys-icl001-2926	132.01	279.54	207.65	267.39	598.27	189.11	182.66	167.54	157.09	174.39	179.28	496.68
gensys-icl002-3128	15.71	26.43	24.81	27.52	102.05	25.03	26.77	26.82	23.47	27.17	24.89	90.57
gensys-icl004-3130	13.84	24.98	22.78	26.24	85.16	27.65	32.77	29.47	27.72	31.47	21.41	82.89
gensys-ukn005-3584	271.6	TO	565.2	TO	TO	515.81	655.96	639.74	475.68	610.71	497.85	TO
gensys-ukn006-3585	88.36	872.7	165.37	179.58	TO	139.98	245.28	202.45	142.57	237.91	156.68	1040.48
gensys-ukn007-3586	0.13	10.22	0.3	3.41	4.64	0.32	0.39	0.38	0.33	0.38	0.36	5.22
gensys-ukn008-3587	3.41	136.03	9.37	10.09	79.35	5.78	6.74	6.79	5.6	5.78	8.04	60.71
grid-pbl-0060-1342	TO	TO	TO	4.65	4.61	1.24	1.24	1.23	1.23	1.24	TO	4.64
gt-012-1301	0.19	0.08	0.56	0.54	0.09	0.57	0.54	0.09	0.58	0.41	0.59	0.41
iso-icl001-2712	0.78	48.28	7.54	15.2	55.32	2.07	6.22	4.28	2.15	3.47	5.86	19.37
iso-icl002-2727	0.28	36.05	2.9	3.53	7.22	0.56	0.95	0.96	0.5	0.89	1.74	4.71
iso-icl003-2728	2.16	63.22	15.76	10.4	27.18	10.28	13.31	13.51	12.76	20.81	10.02	99.54
iso-icl004-2729	3	71.99	24.94	14	25.99	14.45	34.21	25.14	12.66	14.55	12.07	34.7
iso-icl005-2730	3.78	56.02	18.23	15.77	40.18	7.67	11.1	14.2	6.66	10.56	21.47	60.64
iso-icl006-2731	3.28	59.56	25.83	31.09	66.3	6.99	9.68	17.37	6.04	17.53	35.37	60.19
iso-icl007-2732	2.66	47.52	11.55	15.23	53.45	4.59	10.95	10.52	8.11	7.66	16.69	28.7
iso-icl008-2733	1.81	41.06	11.69	12.34	34.06	2.01	4.4	6.29	2.31	6.41	10.33	17.1
iso-icl009-2734	3.84	61.99	9.72	24.28	62.84	8.62	12.19	18.09	8.4	9.1	18.91	74.74

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Table B.2 – continued from previous page

Instance	NOR	CH	PY	PYP1	PYP2	PRPY	PRPYP1	PRPYP2	PRS	PRSP	S	SP
iso-icl100-3334	0.05	2.2	0.1	0.12	0.2	0.06	0.1	0.18	0.05	0.12	0.08	0.18
iso-ukn001-2740	1.65	51.06	13.33	15.83	25.55	3.22	3.76	5.3	2.58	5.07	7.39	43.86
iso-ukn002-2676	2.71	86.38	17.66	15.7	61.39	12.92	16.43	21.19	6.46	23.67	11.62	23.28
iso-ukn003-2677	1.84	61.47	25.62	27.54	62.88	6.14	11.82	11.83	6.93	10.52	14.74	42.42
iso-ukn004-2739	2.57	57.47	14.03	15.32	41.89	5.22	6.64	10.49	5.94	7.94	10.48	37.2
iso-ukn005-3386	0.08	5.49	0.11	0.18	0.31	0.12	0.18	0.14	0.16	0.14	0.12	0.42
iso-ukn007-3388	0.08	3.58	0.1	0.2	0.38	0.12	0.24	0.25	0.15	0.2	0.14	0.34
iso-ukn008-3389	0.09	5.32	0.25	0.29	0.55	0.22	0.39	0.64	0.21	0.44	0.18	0.55
iso-ukn009-3390	0.06	2.71	0.08	0.17	0.24	0.13	0.18	0.19	0.1	0.18	0.09	0.28
logistics-rotate-06t5-1136	0.06	0.17	0.12	0.12	0.13	0.12	0.13	0.13	0.1	0.1	0.1	0.1
logistics-rotate-07t5-1137	0.89	1.56	1.7	1.57	0.9	1.7	1.56	0.91	2.11	4.02	2.09	4.02
php-010-009-1185	3.84	4.99	4.38	2.98	3.83	4.38	2.98	3.84	3.98	3.06	3.98	3.08
php-012-010-1172	153.91	90.09	98.34	109	102.5	97.98	108.9	102.76	154.81	109.8	154.92	109.37

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