Input/Output Format and Solver Requirements for the Competitions of Pseudo-Boolean Solvers

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1 Introduction

This document details the input and output format that a solver must respect in order to enter the pseudo-Boolean competition. Section 2 explains why integers used in the formula can be of arbitrary size, but also specifies that one does not have to use arbitrary precision libraries to enter the competition. Section 3 details the syntax of the input files that a solver has to read. Three different problems can be expressed: PBS (Pseudo-Boolean Satisfaction), PBO (Pseudo-Boolean Optimization) and WBO (Weighted-Boolean Optimization). Besides, the syntax of two different kinds of constraints are specified: linear and non-linear constraints. Section 4 details how the solver must communicate its results. Section 5 explains how solvers are ranked and what happens when a solver is found to be incorrect. At last, Section 6 details the requirements for submitting a solver.

2 Size of integers

One problem that may occur when solving a linear pseudo-Boolean formula is integer overflow. Usually, programs use integers of size corresponding to the processor registers. On the usual 32 bits platforms, this means that the biggest positive integer is only 2,147,483,647 when using the int type (C/C++/Java). This limit is fairly easy to reach. Using 64 bits integers gives a more comfortable limit but doesn't really solve the problem.

Notice that it's fairly easy and natural to get constraints with big integers. For example, if you need to encode that A=B+C where A, B, C are integers, you may just want to write that $\sum_i 2^i.A_i = \sum_i 2^i.B_i + \sum_i 2^i.C_i$. As soon as the size of A, B, C equals the size of the integers used by the solver, we get an integer overflow problem. Another natural example is the encoding of the factorization of an integer.

As far as pseudo-Boolean solver are concerned, integer overflow can occur either during the input of the formula or during the resolution of the formula and will have different effect on the solver capabilities:

- during the input of the formula
  If a solver doesn't use big enough integers, it will fail to read some input file with large integers. This is a minor problem provided that this failure is either detected of at least documented in the solver manual.

- during the resolution of the formula
  This problem is more serious because it will break the correctness of the prover in ways that will be subtle to identify. Suppose that each constraint in the formula contains only small numbers (i.e. such that their sum fits into an integer). If the solver computes new constraints or simply new weights, it may from time to time overflow the limit of the integer it uses internally and give a wrong answer.

Such integer overflows are a concern for the evaluation because we expect to get some wrong answer from time to time on a few benchmarks. On the other hand, integer overflows are easy to fix and are related to the implementation and not to the algorithm used by the solver. One just has to use a multiple precision integer library to get rid of the problem. Of course, computations will be a little bit slower with this kind of library but this is the price to pay for correctness.

Some example of multiple precision libraries:

- GNU Multiple Precision Arithmetic Library for C/C++ (`http://gmplib.org/`)

- the BigInteger class in Java (`http://java.sun.com/javase/6/docs/api/java/math/BigInteger.html`)

Our policy for the competitions is

- to specify a format which doesn't hide this problem by specifying that integers may be of arbitrary size

- to classify benchmarks according to the size of the coefficients they contain (small or big integers)

- to ask submitters to register their solver in the category of benchmarks which it is able to solve

Any solver (subject or not to integer overflow) is welcome. You are not required to modify your solver to use big integers ! You are just required to register in the categories of benchmarks which your solver supports (see Section 6.1).

3 Input Format

This section details the input format for

- Pseudo-Boolean Satisfaction (PBS) instances
  the solver must find an interpretation which satisfies each constraint (decision problem)
- Pseudo-Boolean Optimization (PBO) instances
  the solver must find an interpretation which satisfies each constraint and minimizes the value of an objective function (optimization problem)
- Weighted Boolean Optimization (WBO) instances
  the solver must find an interpretation which minimizes the cost of violated constraints (optimization problem)

The input file format for each problem is a variant of the OPB format (see the end of the README file in the distribution of OPBDP `http://opbdp.sourceforge.net/`).

SPECIFIC RULES FOR THE PB COMPETITION

In order to facilitate the participation of a solver to the competition, some extra assumptions are guaranteed to hold during the competition. These assumptions are described in this kind of frame. However, high quality solvers are encouraged not to rely on these assumptions since they do not necessarily hold outside the competition environment.

3.1 Pseudo-Boolean Satisfaction (PBS) and Pseudo-Boolean Optimization (PBO)

A PBO file and a PBS file only differ by the presence of an objective function (starting with the keyword `min:`) at the beginning of the file.

Lines beginning with a star are comments and can appear anywhere in the files. A PBS file contains a list of pseudo-Boolean constraints. Each pseudo-Boolean (PB) constraint consists of a left side (a list of weighted Boolean terms), a comparison operator and a right side which is an integer constant. Since PB constraints can be normalized, only two comparison operators are allowed (greater than, equal). A PBO file contains an objective function followed by the constraints.

The syntax of these files can be described by a simple BNF grammar (see `http://en.wikipedia.org/wiki/Backus-Naur_form`). `<formula>` is the start symbol of this grammar.

```
<formula>::=
    <sequence_of_comments>
    [<objective>]
    <sequence_of_comments_or_constraints>

<sequence_of_comments>::=
    <comment> [<sequence_of_comments>]
```

```
<comment>::=
    "*" <any_sequence_of_characters_other_than_EOL> <EOL>

<sequence_of_comments_or_constraints>::=
    <comment_or_constraint>
    [<sequence_of_comments_or_constraints>]

<comment_or_constraint>::=
    <comment>|<constraint>

<objective>::=
    "min:" <zeroOrMoreSpace> <sum>  ";"

<constraint>::=
    <sum> <relational_operator>
    <zeroOrMoreSpace> <integer> <zeroOrMoreSpace> ";"

<sum>::=
    <weightedterm> | <weightedterm> <sum>

<weightedterm>::=
    <integer> <oneOrMoreSpace> <term> <oneOrMoreSpace>

<integer>::=
    <unsigned_integer>
    | "+" <unsigned_integer>
    | "-" <unsigned_integer>

<unsigned_integer>::=
    <digit> | <digit><unsigned_integer>

<relational_operator>::=
    ">=" | "="

<variablename>::=
    "x" <unsigned_integer>

<oneOrMoreSpace>::=
    " " [<oneOrMoreSpace>]

<zeroOrMoreSpace>::=
    [" " <zeroOrMoreSpace>]
```

The input format allows the specification of both linear and non-linear pseudo-Boolean instances. The definition of <term> will be given in the corresponding subsections.

This grammar let us write a very simple parser and avoid some ambiguities present in the original description of the OPB format. At the same time, the format remains easily human readable and is mostly compatible with solvers using the OPB format.

Notice that integers may be of arbitrary size (see section 2).

Some details:

- A line starting with a '*' is a comment and can be ignored. Comment lines are allowed anywhere in the file.
- Each non comment line must end with a semicolon ';'

- In a PBO instance, the first non comment line is an objective function to minimize. It starts with the word "min:" followed by the linear function to minimize and terminated by a semicolon. No other objective function can be found after this first non comment line.
- A constraint is written on a single line and is terminated by a semicolon.
- A Boolean variable (atom) is named by a lowercase 'x' followed by a strictly positive integer number. The integer number can be considered as a identifier of the variable. This integer identifier is strictly less than 2^{32}. Therefore, a solver can input a variable name by reading a character (to skip the 'x') and then an 32 bits integer.
- Each variable name must be followed by a space
- The weight of a variable may contain an arbitrary number of digits. There must be no space between the sign of an integer and its digits.
- Lines may be very long. Programmers should avoid reading a line as a whole.
- PBS and PBO files have a ".opb" extension.

3.1.1 Linear instances

For linear pseudo-Boolean instances, `<term>` is defined as

```
<term>::=<variablename>
```

SPECIFIC RULES FOR THE PB COMPETITION

- As a hint to perform memory allocation, the first line of a linear instance will be a comment containing the word "#variable=" followed by a space and the number of variables in the file, then a space and the word "#constraint=" followed by a space and the number of constraints in the file. The space between the word and the number is mandatory to make parsing trivial.
- Variable names are guaranteed to range from "x1" to "xN" where N is the total number of variables in the instance (as given on the first line of the file). Each variable between x1 and xN will occur in at least one constraint or the objective function.
- Each variable present in the objective function will occur in at least one constraint.
- The negation of an atom A will not appear in a linear pseudo-Boolean file (it will be translated to 1-A).

Examples

```
* #variable= 5 #constraint= 4
*
* this is a dummy instance
*
min: 1 x2 -1 x3 ;
1 x1 +4 x2 -2 x5 >= 2;
-1  x1 +4   x2 -2   x5 >= +3;
12345678901234567890 x4 +4 x3 >= 10;

* an equality constraint
2 x2 +3 x4 +2 x1 +3 x5 = 5;
```

3.1.2 Non-Linear Instances

The format for non-linear pseudo-Boolean instances is a straightforward generalization of the linear format. The main changes are:

- Both in the objective function and in the constraints, the input format allows the specification of product of literals. Since literals are assigned values from 0,1, a product of literals is interpreted as 1 if and only if all of its literals are assigned to 1. In Boolean terms, a product represents a conjunction of literals.
- Products contain literals instead of variables. Therefore, variable names can be preceded with the character '$\sim$' in order to specify the negative literal of that variable

With these generalizations, it is possible to specify constraints like:

```
3 x1 x2 + 2 ~x3 ~x4 ~x5 -3 x6 >= +2 ;
```

If we would not allow negative literals in the format, we would have to replace this simple term

```
2 ~x3 ~x4 ~x5
```

with the significantly longer expression

```
-2 x3 -2 x4 -2 x5 +2 x3 x4 +2 x3 x5 +2 x4 x5 -2 x3 x4 x5 +2
```

For non-linear instances, `<term>` is defined as

```
<term>::=
    <oneOrMoreLiterals>

<oneOrMoreLiterals>::=
    <literal> | <literal> <oneOrMoreSpace> <oneOrMoreLiterals>

<literal>::=
    <variablename> | "~"<variablename>
```

SPECIFIC RULES FOR THE PB COMPETITION

- A product which contains one single literal will not use a negation (the negation ∼L will be replaced by 1-L during the normalization process)
- For a non-linear instance, the first line will be a comment containing the word "#variable=" followed by a space and the number of variables in the file, then a space and the word "#constraint=" followed by a space and the number of constraints in the file then a space, the word "#product=" and a space, the number of different products of variables present in the file, then a space then the word "sizeproduct=" followed by a space and the total number of literals which appear in different products. These two last informations allow the parsers to compute the total number of linear constraints that will be passed to the solver when the parser is asked to linearize the formula. The keyword "#product=" also clearly indicates that this is a non-linear instance.
- Variables that appear inside a product are guaranteed to be ordered from the lowest to the greatest index. High quality provers are encouraged to avoid relying on this assumption as it may not hold outside the evaluation environment.

Examples The first example only illustrates the syntax (it does not encode any concrete problem).

```
* #variable= 5 #constraint= 4 #product= 5 sizeproduct= 13
*
* this is a dummy instance
*
min: 1 x2 x3 -1 x3 ;
1 x1 +4 x1 ~x2 -2 x5 >=2;
-1 x1 +4 x2 -2 x5 >= 3;
123456789012345678901 x4 +4 x3 >= 10;
2 x2 x3 +3 x4 ~x5 +2 ~x1 x2 +3 ~x1 x2 x3 ~x4 ~x5 = 5 ;
```

This second example encodes a factorization problem (see the comments for the details). For lack of space, the last constraint has been printed on 2 lines but is actually stored on a single line in the file.

```
* #variable= 6 #constraint= 3 #product= 9 sizeproduct= 18
*
* Factorization problem: find the smallest P such that P*Q=N
* P is a 3 bits number (x3 x2 x1)
* Q is a 3 bits number (x6 x5 x4)
* N=35
*
* minimize the value of P
min: +1 x1 +2 x2 +4 x3 ;
* P>=2 (to avoid trivial factorization)
+1 x1 +2 x2 +4 x3  >= 2 ;
* Q>=2 (to avoid trivial factorization)
+1 x4 +2 x5 +4 x6  >= 2 ;
* P*Q=N
+1 x1 x4 +2 x1 x5 +4 x1 x6 +2 x2 x4 +4 x2 x5 +8 x2 x6 +4 x3 x4
                                              +8 x3 x5 +16 x3 x6 = 35;
```

This formula can easily be linearized and transformed into the following linear formula. The parsers provided for the competition are able to perform this linearization automatically.

```
* #variable= 15 #constraint= 21
*
* linearized version of the factorization problem (P*Q=35)
* this linearization can be automatically done by the parsers we
* provide
min: +1 x1 +2 x2 +4 x3;
+1 x1 +2 x2 +4 x3 >= 2;
+1 x4 +2 x5 +4 x6 >= 2;
+1 x7 +2 x8 +4 x9 +2 x10 +4 x11 +8 x12 +4 x13 +8 x14 +16 x15 = 35;
* new variables introduced to represent the products
+1 x7 -1 x1 -1 x4 >= -1;
-2 x7 +1 x1 +1 x4 >= 0;
+1 x8 -1 x1 -1 x5 >= -1;
-2 x8 +1 x1 +1 x5 >= 0;
+1 x9 -1 x1 -1 x6 >= -1;
-2 x9 +1 x1 +1 x6 >= 0;
+1 x10 -1 x2 -1 x4 >= -1;
-2 x10 +1 x2 +1 x4 >= 0;
+1 x11 -1 x2 -1 x5 >= -1;
-2 x11 +1 x2 +1 x5 >= 0;
+1 x12 -1 x2 -1 x6 >= -1;
-2 x12 +1 x2 +1 x6 >= 0;
+1 x13 -1 x3 -1 x4 >= -1;
-2 x13 +1 x3 +1 x4 >= 0;
+1 x14 -1 x3 -1 x5 >= -1;
-2 x14 +1 x3 +1 x5 >= 0;
+1 x15 -1 x3 -1 x6 >= -1;
-2 x15 +1 x3 +1 x6 >= 0;
```

3.2 Weighted Boolean Optimization (WBO)

The Weighted Boolean Optimization (WBO) framework extends the MaxSAT concepts to pseudo-Boolean constraints. In [MMSP09], the WBO framework is defined as follows:

> A Weighted Boolean Optimization (WBO) formula ϕ is composed of two sets of pseudo-Boolean constraints, ϕ_s and ϕ_h, where ϕ_s contains the soft constraints and ϕ_h contains the hard constraints. For each soft constraint $\omega_i \in \phi_s$ there is an associated integer weight $c_i > 0$. The WBO problem consists in finding an assignment to the problem variables such that all hard constraints are satisfied and the total weight of the unsatisfied soft constraints is minimized (i.e. the total weight of satisfied soft constraints is maximized).

The WCSP (Weighted Constraint Satisfaction Problem) uses the notion of top cost T. All interpretation with a cost greater than or equal to T are non admissible and cannot be a solution. This notion is quite natural in practice. Therefore, we choose to refine the definition of the WBO formalism as follows:

The WBO problem consists in finding an assignment to the problem variables such that all hard constraints are satisfied and the total weight of the unsatisfied soft constraints is minimized *and strictly less than* T.

A WBO instance does not contain an objective function. The first non comment line of the file starts with the keyword "soft:", followed by the top cost T and a semi-colon. If $T = \infty$, the top cost can be omitted and the first line is just "soft: ;"

A WBO file will have a '.wbo' extension.

SPECIFIC RULES FOR THE PB COMPETITION

In the PB competition, the top cost will always be specified. When all interpretations are admissible (i.e. when $T = \infty$), T will be given as 1 plus the sum of each soft constraint cost.

In the rest of the file, hard constraints use the same syntax as in PBS files. Soft constraints are prefixed with their cost written in square brackets. As an example, "+1 x1 +2 x2 >= 2 ;" is a hard constraint and "[5] +1 x1 +2 x2 >= 2 ;" is a soft constraint which has a cost of 5.

The differences between the grammar of a PBS/PBO file and the grammar of a WBO file are small and detailed below.

```
<softformula>::=
    <sequence_of_comments>
    <softheader>
    <sequence_of_comments_or_constraints>

<softheader>::=
    "soft:" [<unsigned_integer>] ";"

<comment_or_constraint>::=
    <comment>|<constraint>|<softconstraint>

<softconstraint>::=
    "[" <zeroOrMoreSpace> <unsigned_integer> <zeroOrMoreSpace> "]"
    <constraint>
```

The cost of a soft constraint can be any positive integer (including big integers) as long as it is strictly less than T (otherwise the constraint would be hard).

A WBO instance can be transformed into a PBO instance by introducing extra variables which allow to neutralize soft constraints and adding an objective function which requires to minimize the cost of neutralized soft constraints.

SPECIFIC RULES FOR THE PB COMPETITION

- To give a hint to solvers, the first line of the file will be a comment that will start with the usual information given for a linear, on non-linear file. This line will then contain the keyword `#soft=` followed by a space and the number of soft constraints in the file, then a space, the keyword `mincost=`, a space and the smallest cost of a soft constraint, then a space, the keyword `maxcost=` and the greatest cost used in the file, a space, the keyword `sumcost=`, a space and at last the sum of the soft constraints costs.

  As an example, a WBO instance with only linear constraints could start with the following line:

  ```
  * #variable= 15 #constraint= 21 #soft= 5 mincost= 1 maxcost= 1
    sumcost= 5
  ```

  A WBO instance with non-linear constraints could start with the following line:

  ```
  * #variable= 15 #constraint= 21 #product= 5 sizeproduct= 13
    #soft= 5 mincost= 1 maxcost= 2 sumcost= 9
  ```

- The costs used in the file will be as small as possible (but still may be of arbitrary size if this is needed to encode the problem). This implies that at least one cost will be 1, and if all costs are equal, their value will be 1.

3.2.1 Examples

Example 1 The optimal solution of the instance below is $x_1 = 0$ and has a cost of 2.

```
* #variable= 1 #constraint= 2 #soft= 2 mincost= 2 maxcost= 3 sumcost= 5
soft: 6 ;
[2] +1 x1 >= 1 ;
[3] -1 x1 >= 0 ;
```

A solver should answer (see Section 4 for explanations)

```
o 2
s OPTIMUM FOUND
v -x1
```

Example 2 The optimal solution of the instance below is $x_1 = 0, x_2 = 1$ and has a cost of 2.

```
* #variable= 2 #constraint= 3 #soft= 2 mincost= 2 maxcost= 3 sumcost= 5
soft: 6 ;
[2] +1 x1 >= 1 ;
[3] +1 x2 >= 1 ;
-1 x1 -1 x2 >= -1 ;
```

A solver should answer

```
o 2
s OPTIMUM FOUND
v -x1 x2
```

Example 3 The instance below has no solution at all (the minimal cost is 6 which is not admissible).

```
* #variable= 4 #constraint= 6 #soft= 4 mincost= 2 maxcost= 5 sumcost= 14
soft: 6 ;
[2] +1 x1 >= 1 ;
[3] +1 x2 >= 1 ;
[4] +1 x3 >= 1 ;
[5] +1 x4 >= 1 ;
-1 x1 -1 x2 >= -1 ;
-1 x3 -1 x4 >= -1 ;
```

A solver should answer

```
s UNSATISFIABLE
```

4 Output Format

Solvers must print messages to the standard output and those messages will be used to check the results. The output format is inspired by the DIMACS output specification of the SAT competition and may be used to manually check some results.

4.1 Messages

With the exception of the "o " line, there is no specific order in the solvers output lines. However, all lines, according to its first char, must belong to one of the four following categories:

- **comments ("c " lines)**

  These lines start by the two characters: lower case c followed by a space (ASCII code 32).

  These lines are optional and may appear anywhere in the solver output.

  They contain any information that authors want to emphasize, such as #backtracks, #flips,... or internal cpu-time. They are recorded by the evaluation environment for later viewing but are otherwise ignored. At most one megabyte of solver output will be recorded. So, if a solver is very verbose, some comments may be lost.

  Submitters are advised to avoid printing comment lines which may be useful in an interactive environment but otherwise useless in a batch environment. For example, outputing comment lines with the number of constraints read so far only increases the size of the logs with no benefit.

  If a solver is really too verbose, the organizers will ask the submitter to remove some comment lines.

- **value of the objective function (for PBO), or current cost (for WBO) (”o ” lines)**

  These lines start by the two characters: lower case o followed by a space (ASCII code 32).

  These lines are mandatory for incomplete solvers. As far as complete solvers are concerned, they are not strictly mandatory but solvers are strongly invited to print them.

  These lines should be printed only for optimisation instances (PBO, WBO). They will be ignored for PBS instances.

  Whenever the solver finds a solution with a better value of the objective function (PBO) or of the current cost (WBO), it is asked to print an ”o ” line with the current value of the objective function/cost. Therefore, an ”o ” line must contain the lower case o followed by a space and then by an integer which represents the better value of the objective function/cost. The integer output on this line must be the value of the objective function/cost as found in the instance file. ”o ” lines should be output as soon as the solver finds a better solution and be ended by a standard Unix end of line character (’\n’). Programmers are advised to flush immediately the output stream.

  Example:

  The instance file contains an objective function `min: 1 x1 +1 x2 -1 x3`

  Let f be this objective function found in the file.

  The solver chooses to rewrite this function as $f' = x_1 + x_2 + not(x_3)$ to get only positive weights. It must remember that $f = f' - 1$ (since $-x = not(x) - 1$). When it finds a solution x_1=true, x_2=true, x_3=false, it must output ”o 2” (f' has value 3 with this assignment but f has value 2). If x_1=false, x_2=false and x_3=true is a solution, the solver may successively output

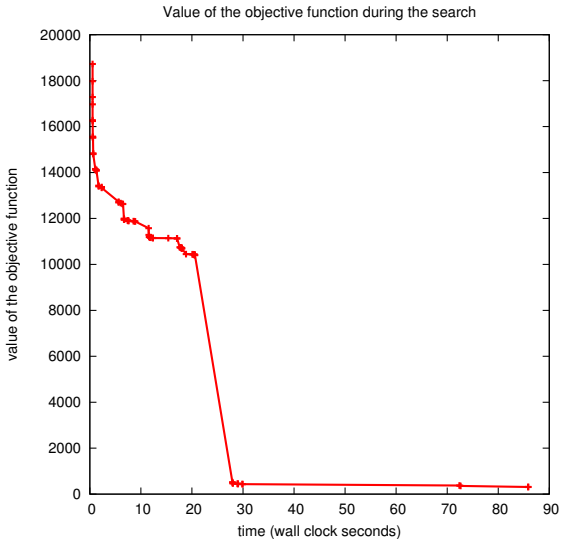
```
o 2
o 1
o -1
s OPTIMUM FOUND
v -x1 -x2 x3
```

  The evaluation environment will automatically timestamp each of these lines so that it is possible to know when the solver has found a better solution and how good the solution was. The goal is to analyse the way solvers progress toward the best solution. As an illustration, here is a sample of the output of a solver, with each line timestamped (first column, expressed in seconds of wall clock time since the beginning of the program).

```
0.00     c Time Limit set via TIMEOUT to 1800
0.51     c Initial problem consists of 6774 variables and 100 constraints.
0.55     c No problem reductions applied in OPT. instance.
0.55     c    preprocess terminated. Elapsed time: 0.45
```

```
0.55     c Initial Lower Bound: 0
0.63     o 235947
0.63     o 226466
0.63     o 217758
0.75     o 186498
1.16     o 178319
2.42     o 168389
3.13     c Restart #1 #Var: 6774 LB: 0 @ 3.03
4.89     c Restart #2 #Var: 6774 LB: 0 @ 4.79
5.73     o 160358
6.44     o 159206
7.52     o 150077
9.09     o 149533
12.14    o 140853
17.74    o 140264
19.61    o 131636
29.81    o 15450
34.00    o 7066
41.66    o 5000
84.01    o 3905
84.01    c NEW SOLUTION FOUND: 3905 @ 83.873
84.61    s OPTIMUM FOUND
84.61    v -x1 -x2 -x3 x4 -x5 -x6 -x7 -x8 -x9 -x10 -x11 -x12 -x13 -x14 -x15
84.61    v -x16 -x17 -x18 -x19 -x20 -x21 -x22 -x23 -x24 -x25 -x26 -x27 -x28
84.61    c Total time: 84.478 s
```

and here is an example of graph which can be generated from such 'o ' lines



- **solution ("s " lines)**

  This line starts by the two characters: lower case s followed by a space (ASCII code 32).

  Only one such line is allowed.

  It is mandatory.

  This line gives the answer of the solver. It must be one of the following answers:

- `s UNSUPPORTED`
  This line should be printed by the solver when it discovers that the input file contains a feature that the solver does not support. As an example, a solver which only understand linear constraint should print this line when it reads a non-linear constraint.
- `s SATISFIABLE`
  This line indicates that the solver has found a model of the formula, and in such a case, a "v " line is mandatory.

  For decision problems, this line must be printed when the solver has found a solution.

  For optimization problems, this line must be in the output when the solver has found a solution but it can not prove that this solution gives the best value of the objective function (PBO) or of the cost (WBO).
- `s OPTIMUM FOUND`
  This line must be printed when the solver has found a model and it can prove that no other solution is better.

  For PBO instances, this means that no other solution will give a better value of the objective function than the one obtained with this model. Let v be the value of the objective obtained with the valuation output by the solver. Giving this result is a commitment that the formula extended with the constraint objective$<$v is unsatisfiable.

  For WBO instances, this answer means that no other interpretation has a smaller cost.

  This answer must not be used for PBS instances.
- `s UNSATISFIABLE`
  This line must be output when the solver can prove that the formula has no solution.
- `s UNKNOWN`
  This line must be output in any other case, i.e. when the solver is not able to tell anything about the formula.

It is of uttermost importance to respect the exact spelling of these answers. Any mistake in the writing of these lines will cause the answer to be disregarded.

Solvers are not required to provide any specific exit code corresponding to their answer.

If the solver does not output a *solution* line, or if the solution line is misspelled, then UNKNOWN will be assumed.

- **values ("v " lines)**

  This line starts by the two characters: lower case v followed by a space (ASCII code 32).

  More than one "v " line is allowed but the evaluation environment will act as if their content was merged.

It is mandatory when the instance is satisfiable.

If the solver finds a solution (it outputs "s SATISFIABLE" or "s OPTIMUM FOUND"), it must provide a solution. For PBS or PBO, this solution is a model (or an implicant) of the instance that will be used to check the correctness of the answer, i.e., it must provide a list of non-contradictory literals which, when interpreted to true, makes every constraint of the input formula true. For WBO, the solution is just an interpretation that satisfies each hard constraint and minimizes the cost of unsatisfied soft constraints. When optimization is considered, this set of literals should provide an interpretation such that the value of the objective funtion/cost corresponds to the best one that the solver was able to find. The negation of a literal is denoted by a minus sign immediately followed by the identifier of the variable. The solution line MUST define the value of EACH VARIABLE. The order of literals does not matter. Arbitrary white space characters, including ordinary white spaces, newline and tabulation characters, are allowed between the literals, as long as each line containing the literals is a *values* line, i.e. it begins with the two characters "v ".

The *values* lines should only appear with SATISFIABLE instance (including instances for which an OPTIMUM was FOUND).

Values lines must be terminated by a Line Feed character (the usual Unix line terminator '\n'. A "v " line which does not end with that terminator will be ignored because it will be considered that the solver was interrupted before it could print a complete solution.

For instance, the following outputs are valid for the instances given in example:

```
mycomputer: $ ./mysolver myinstance-sat
c mysolver 6.55957 starting with TIMEOUT fixed to 1000s
c Trying to guess a solution...
s SATISFIABLE
v x1 x2 -x5 x4 -x3
c Done (mycputime is 234s).

mycomputer: $ ./mysolver myinstance-unsat
c mysolver 6.55957 starting with TIMEOUT fixed to 1000s
c Trying to guess a solution...
c Contradiction found!
s UNSATISFIABLE
c Done (mycputime is 2s).
```

Note that we do not require a proof for unsatisfiability.

5 Ranking of solvers

Basically, solvers will be ranked on the number of definitive answers[1] they give in each category. Ties are broken on the cumulated CPU time to give these answers.

[1]Definitive answers in the DEC categories are SATISFIABLE and UNSATISFIABLE, definitive answers in the OPT and SOFT categories are OPTIMUM FOUND and UNSATISFIABLE

Other ranking schemes may be introduced to help identify remarkable features.
A solver is declared to give a wrong answer in the following cases:

- It outputs UNSATISFIABLE for an instance which can be proved to be satisfiable.
- For PBS and PBO, it outputs SATISFIABLE or OPTIMUM FOUND, but provides an assignment which does not satisfy each constraint. The only exception is when the solver outputs an incomplete "v " line (which does not end by '\n') in which case it is assumed that the solver was interrupted before it could output the complete model and the answer will be considered as UNKNOWN.
- It outputs OPTIMUM FOUND but there exists an interpretation with a better value of the objective function/cost that the one obtained from the interpretation found.

When a solver provides even one single wrong answer in a given category of benchmarks, the solver's results in that category will be excluded from the final evaluation results because they cannot be trusted. Exceptionally, the organizers may decide to present separately the results of such a solver but only if it obtained particularly good results and if a detailed explanation of the problem as well as a solution is provided by the submitters.

A solver which ends without giving any solution, or just crashes for some reason (internal bugs...), is simply considered as giving an UNKNOWN result. It is bugged, but not incorrect.

6 Requirements for submitting a solver

6.1 Categories

Because not all solvers are able to solve every kind of instances, you will be asked when you register your solver to indicate which category of benchmarks it is able to handle. This year, we have up to 12 categories defined by the ability of the solver to

- deal with PBS, PBO or WBO instances,
- deal with linear or non linear constraints,
- deal with small or big integers

Three categories are defined based on the kind of problem to solve:

- Category DEC (decision problem, pseudo-Boolean satisfaction (PBS))
  Benchmarks in this category contain neither an objective function nor soft constraints. The solver is expected to answer SATISFIABLE or UNSATISFIABLE. All solvers should register in this category. This category was called SAT/UNSAT in previous evaluations.

- Category OPT (pseudo-Boolean optimisation problem (PBO))
  Benchmarks in this category contain an objective function which should be minimized (and hence contain no soft constraint). Complete solvers entering this category must be able to find the best solution and give an OPTIMUM FOUND answer.

- Category SOFT (weighted boolean optimisation problem (WBO))
  Benchmarks in this category contain soft constraints. Complete solvers entering this category must be able to find the best solution and give an OPTIMUM FOUND answer.

Two categories are defined based on the kind of contraints contained in the instance:

- Category "linear constraints" (LIN)
  All contraints in the instance are linear pseudo-Boolean constraints. All solvers should register in this category.

- Category "non linear constraints" (NLC)
  At least one constraint (or the objective function) is non linear, meaning that it contains at least one product of Boolean variables. A non linear constraint or objective function can always be linearized by introducing new variables.

  As we provide parsers which will automatically perform a basic linearization, we expect that all solvers will register in this category. Solvers which do not register in this category will be run on a linearized version of the benchmark using default techniques.

As explained in the section on the input format (see below), benchmarks may contain arbitrarily long integers that do not fit in a usual 32-bits integer. Section 2 explains why we consider that a strong solver should use a multiple precision integer library. However, we do not require that you modify your existing solver to use big integers. We just need that you register your solver in the categories which it is able to solve. This is an important decision because registering a solver in a given category is a claim that it will give correct answers for each benchmark in that category.

Concerning the integers values, two categories are defined

- Category "small integers" (SMALLINT)
  Benchmarks in this category contain only small integers, which means that they contain no constraint with a sum of coefficients greater than or equal to 2^{21} (each number has up to 20 bits). Solvers which use 32-bits integers are most probably safe, unless they use some fancy learning scheme. All solvers should register in this category.

- Category "big integers" (BIGINT)
  Benchmarks in this category have at least one constraint with a sum of coefficients greater than or equal to 2^{21} (at least 21 bits). Only solvers with support for big integers should register in this category.

6.2 Complete and incomplete solvers

Complete solvers are solvers which can always decide if the formula is satisfiable or not, provided they are given enough time and memory. Incomplete solvers are able to give some answers (e.g. SATISFIABLE) but not all. They may loop endlessly in a number of cases. Local search algorithms are examples of incomplete solvers. There is a high probability that they find a solution if the instance is satisfiable, but they will not be able to prove unsatisfiability.

Both kinds of solvers are welcome in this evaluation. Submitters will have to indicate if their solver is complete or incomplete on the submission form.

6.3 Complete solvers

There is no special requirement about complete solvers. See the input and output format that all solvers must respect for details.

6.4 Incomplete solvers

Incomplete solvers are definitely welcome in the competition. Despite the fact that they will never answer UNSATISFIABLE or OPTIMUM FOUND, incomplete solvers can be registered in each of the DEC, OPT and SOFT categories.

In the DEC category, an incomplete solver will stop as soon as it finds a solution and will time out if it can't find one. The only difference with a complete solver is that it will time out systematically on unsatisfiable instances.

In the two optimisation categories, an incomplete solver will systematically time out because it will be unable to prove that it has found the optimum solution. Yet, it may have found the optimum value well before the time out. In order to get relevant informations in these categories, an incomplete solver must fulfill two requirements:

1. it must intercept the SIGTERM sent to the solver on timeout and output either "s UNKNOWN" or "s SATISFIABLE" with the "v " line corresponding to the best model it has found

2. it MUST output "o " lines whenever it finds a better solution so that, even if the solver always timeout, the timestamp of the last "o " line indicates when the best solution was found. Keep in mind that it is the evaluation environment which is in charge of timestamping "o " lines.

6.5 Execution environment

Solvers will run on a cluster of computers using the Linux operating system. They will run under the control of another program (runsolver) which will enforce some limits on the memory and the total CPU time used by the program.

Solvers will be run inside a sandbox that will prevent unauthorized use of the system (network connections, file creation outside the allowed directory, among others).

Solvers can be run as either as 32 bits or 64 bits applications. If you submit an executable, you are required to provide us with an ELF executable (preferably statically

linked). Authors submitting solvers in source form will have to specify if it should be compiled in 32 bits or 64 bits mode.

Two executions of a solver with the same parameters and system resources must output the same result in approximately the same time (so that the experiments can be repeated).

During the submission process, you will be asked to provide the organizers with a suggested command line that should be used to run your solver. In this command line, you will be asked to use the following placeholders, which will be replaced by the actual informations by the evaluation environment.

- BENCHNAME will be replaced by the name of the file containing the instance to solve. Obviously, the solver must use this parameter or one of the following variants: BENCHNAMENOEXT (name of the file with path but without extension), BENCHNAMENOPATH (name of the file without path but with extension), BENCHNAMENOPATHNOEXT (name of the file without path nor extension).
- RANDOMSEED will be replaced by a random seed which is a number between 0 and 4294967295. This parameter MUST be used to initialize the random number generator when the solver uses random numbers. It is recorded by the evaluation environment and will allow to run the program on a given instance under the same conditions if necessary.
- TIMELIMIT (or TIMEOUT) represents the total CPU time (in seconds) that the solver may use before being killed. May be used to adapt the solver strategy.
- MEMLIMIT represents the total amount of memory (in MiB) that the solver may use before being killed. May be used to adapt the solver strategy.
- TMPDIR is the name of the only directory where the solver is allowed to read/write temporary files
- DIR is the name of the directory where the solver files will be stored

Examples of command lines:

```
DIR/mysolver BENCHNAME RANDOMSEED
DIR/mysolver --mem-limit=MEMLIMIT --time-limit=TIMELIMIT \
             --tmpdir=TMPDIR BENCHNAME
java -jar DIR/mysolver.jar -c DIR/mysolver.conf BENCHNAME
```

As an example, these command lines could be expanded by the evaluation environment as

```
/solver10/mysolver /tmp/file.opb 1720968
/solver10/mysolver --mem-limit=900 --time-limit=1200 \
                   --tmpdir=/tmp/job12345 /tmp/file.opb
java -jar /solver10/mysolver.jar -c /solver10/mysolver.conf /tmp/file.opb
```

The command line provided by the submitter is only a suggested command line. Organizers may have to modify this command line (e.g. memory limits of the Java Virtual Machine (JVM) may have to be modified to cope with the actual memory limits).

The solver may also (optionally) use the values of the following environment variables:

- TIMELIMIT (or TIMEOUT) (the number of seconds it will be allowed to run)
- MEMLIMIT (the amount of RAM in MiB available to the solver)
- TMPDIR (the absolute pathname of the only directory where the solver is allowed to create temporary files)

After TIMEOUT seconds have elapsed, the solver will first receive a SIGTERM to give it a chance to output the best solution it found so far (in the case of an optimization problem). One second later, the program will receive a SIGKILL signal from the controlling program to terminate the solver.

The solver cannot write to any file except standard output, standard error and files in the TMPDIR directory. A solver is not allowed to open any network connection or launch unexpected external commands. Solvers may use several processes or threads.

References

[MMSP09] Vasco Manquinho, Joao Marques-Silva, and Jordi Planes, *Algorithms for Weighted Boolean Optimization*, SAT '09: Proceedings of the 12th International Conference on Theory and Applications of Satisfiability Testing (Berlin, Heidelberg), Springer-Verlag, 2009, pp. 495–508.