Practical SAT Solving (ST 2025) | Assignment 2

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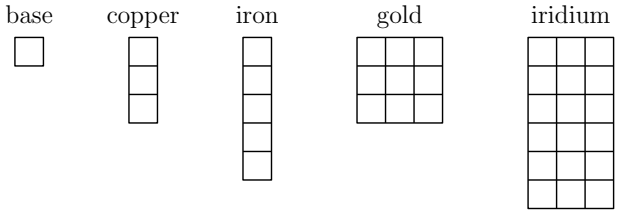
1 Competition: SDVSTP (8(+8) Points)

Consider the well-known and industrially relevant *Stardew Valley Soil Tilling Problem* (SDVSTP), which we also talked about (in a slightly simpler form) in the 0th exercise.
We have a $w \times h$ 2D grid G of "soil" cells. Each of the $w \cdot h$ cells is in exactly one of the following states: *tilled* (T), *should be tilled* (+), or *must not be tilled* (−). We also define the following five *patterns* (corresponding to five increasing *charging levels* of a hoe):



We further define *action* $a = (p, r, x, y)$ as follows: Rotate the pattern $p \in \{\text{base, copper, iron, gold, iridium}\}$ by $r \in \{0°, 90°\}$ and then align its *upper left corner* with grid position (x, y). Then a is *applicable* if the pattern is fully contained within G. Applying a changes all cells in G under the pattern to state T.

A *solution* for G is a set of applicable actions $A = \{a_1, a_2, \ldots, a_k\}$ such that applying each action in A transforms G into the grid G' where all cells that were initially in state + are in state T and all cells that were initially in state − are still in state −. The objective is to find a solution that minimizes k.

Devise a SAT-based SDVSTP solver. Your program should take a single argument, the path to an input file in the straight-forward `.sdvstp` format, structured as in the example in Fig. 1 (left). The solver should output a line "`s SOLUTION k`", where k is the minimum number of required actions, followed by k lines describing each individual action $(p, r, x, y) \in A$, as in Fig. 1 (center).

```
p sdvstp 8 5
++++++++
++++++++
++T--+++
+TT--+++
-------+
```

```
s SOLUTION 6
v gold    0 0 0
v gold    0 5 1
v iron   90 3 0
v copper 90 3 1
v base    0 0 3
v base    0 7 4
```

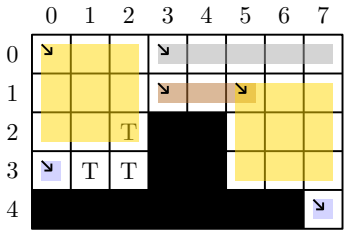


Figure 1: Left: Example `.sdvstp` input file specifying an 8×5 grid. Center: Possible corresponding output of the solver (columns aligned only for better readability). Right: illustration of the grid and the output solution, with the top-left "anchor point" of each pattern marked with an arrow.

You get 8 points for a correct SDVSTP solver that is able to solve easy instances within a few minutes. The best performing solution is awarded double the points.

Code skeleton: `https://github.com/satlecture/kit2025/blob/main/code/src/sdvstp/sdvstp.cc`

Some benchmark instances: `https://github.com/satlecture/kit2025/tree/main/exercises/sdvstp`

2 CDCL (3+6 Points)

2.1 a)

Simulate the CDCL algorithm by hand on the formula F. Select branching literals in the order $x_1, x_2, x_3, ...$ Draw the implication graph once a conflict occurs, learn the 1-UIP clause and continue CDCL search with the variable implied by the asserting learned clause. If everything goes right you should only encounter a single conflict before arriving a satisfying assignment. To emphasize the structure, each variable x_i is just written as i and it's negation $\bar{x}_i$ as $-i$. So for example, $\bar{x}_4$ is written as -4 and x_8 as 8.

$$F = \{\{-1, -2, -4\}, \{-3, 6\}, \{-5, -6, 8\}, \{4, -8, 10\}, \tag{1}$$
$$\{7, 9\}, \{-2, -8, 9\}, \{-1, -9 - 10\}, \{-5, 8, 9\}\} \tag{2}$$

2.2 b)

Repeat the CDCL algorithm, now for the larger formula F'. Again, select branching literals again in the order $x_1, x_2, x_3, ...$ Draw the implication graph at every conflict and give the learned 1-UIP clause. Provide the final assignment.

$$\begin{aligned} F' = &\{\{1, 13\}, \{-1, -2, 14\}, \{3, 15\}, \{4, 16\}, \{-5, -3, 6\}, \\ &\{-5, -7\}, \{-6, 7, 8\}, \{-4, -8, -9\}, \{-1, 9, -10\}, \\ &\{9, 11, -14\}, \{10, -11, 12\}, \{-2, -11, -12\}\} \end{aligned} \tag{3}$$

3 Local Search Competition (7(+7) Points)

Using the methods from the lecture, as well as any others you find in the literature or invent yourself, implement an efficient local search SAT solver. The solver should accept one argument, which is the path to an input file in DIMACS format. Easy-to-solve, satisfiable instances can be found in the Global Benchmark Database (GBD) [1]. You can use the parser provided in the lecture [2]. The output format of your solver should adhere to the format used in the SAT competition which is specified online [3]. Solvers will be evaluated on a random set of satisfiable instances, and we will verify that the model is correct. Additionally, we will test your solver on unsatifiable instances.

[1] **Benchmark Instances:** `https://benchmark-database.de/?minisat1m=yes&result=sat`.

[2] **CNF Parser:** `https://github.com/satlecture/kit2025/blob/main/code/src/util/CNFFormula.h`.

[3] **Output Format:** `https://satcompetition.github.io/2025/output.html`.

You will receive seven points for a local search solver that can correctly solve easy instances in a few minutes. The solution with the best performance will receive double the points.