Over-subscription planning with Boolean Optimization: An accessment of state-of-the-art solutions

Marco Maratea and Luca Pulina

DIST - University of Genova
DEIS - University of Sassari

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Context

- Planning as Satisfiability (SAT) is the best approach for solving classical planning problems optimally wrt makespan
- The role of "optimization/preferences" in recent International Planning Competitions (IPCs) has increased and become central to design more and more realistic problems
- An idea is to reduce IPC planning problems to optimization problems that (*i*) extend SAT and (*ii*) can deal with optimizations/preferences

Here....

We

1. show a reduction of IPC-5/IPC-6 benchmarks, at fixed makespan, to Boolean Optimization problems (PB, Max-SAT, ASP, ILP) that can natively handle (*i*) integer numbers and (*ii*) linear optimization functions
2. run SOTA PB, Max-SAT, ASP and ILP solvers on benchmarks coming from the reduced problems, which include planning with actions costs and soft preconditions, and soft goals

in order to

- evaluate PB, Max-SAT, ASP and ILP solvers on this application domain
- possibly identify challenging optimization benchmarks

Example: TPP domain – soft preconditions (I)

```
(:action drive
:parameters (?t - truck ?from ?to - place)
:precondition (and (at ?t ?from) (connected ?from ?to)
                   (preference p-drive (and
                                (ready-to-load goods1 ?from level0)
                                (ready-to-load goods2 ?from level0)
                                (ready-to-load goods3 ?from level0))))
:effect (and (not (at ?t ?from)) (at ?t ?to)))
```

(1)

Action drive, which contains one preference formula, is split into two (mutually exclusive) actions:

- drive itself, where soft preconditions are considered as hard; and
- a second action, where soft preconditions are considered as hard and negated, with a literal is added as effect (goal-drive)

Example: TPP domain – soft preconditions (II)

```
(:action drive
:parameters (?t - truck ?from ?to - place)
:precondition (and (at ?t ?from) (connected ?from ?to)
                   (ready-to-load goods1 ?from level0)
                   (ready-to-load goods2 ?from level0)
                   (ready-to-load goods3 ?from level0))
:effect (and (not (at ?t ?from)) (at ?t ?to)))
```

(2)

```
(:action drive'
:parameters (?t - truck ?from ?to - place)
:precondition (and (at ?t ?from) (connected ?from ?to)
                   (not (and (ready-to-load goods1 ?from level0)
                             (ready-to-load goods2 ?from level0)
                             (ready-to-load goods3 ?from level0))))
:effect (and (not (at ?t ?from)) (at ?t ?to) (goal-drive)))
```

(3)

Example: TPP domain – soft goals and metric

```
(:goal (and
        (preference p4A
                (and (ready-to-load goods3 market1 level0)
                     (loaded goods3 truck1 level0)))
        ...
        (preference p0A (stored goods3 level1))
        ...))
```
(4)

```
(:metric minimize (+ (* 1 (is-violated p0A))
                     ...
                     (* 16 (is-violated p4A))
                     (* 1 (is-violated p-drive))))
```

For each goal preference, a dummy action is introduced, e.g.,

```
(:action dummy-p4A
:parameters ()
:precondition (and (ready-to-load goods3 market1 level0)
                   (loaded goods3 truck1 level0))
:effect (and (goal-p4A))).
```
(5)

Generating the optimization problem (e.g., PB)

Given the "adapted" IPC-5 problem Π':

1. it is compiled into a STRIPS problem Π''
2. Π'', at fixed makespan, is reduced to a PB problem by
   - converting each SAT clause from classical SAT-based encoding (with solution π) generated by SATPLAN into a corresponding PB constraint; and
   - specifying the optimization function

The optimization function of our working example is

$$\textit{max:} +1\ \pi(\textit{goal-p0A}) + \ldots +16\ \pi(\textit{goal-p4A}) - \sum_{i=1}^{n} +1\ \pi(\textit{goal-drive}_i)$$

or, if an action can be executed at most once

$$\textit{max:} +1\ \pi(\textit{goal-p0A}) + \ldots +16\ \pi(\textit{goal-p4A}) -1\ \pi(\textit{goal-drive})$$

IPC-6 problems also contain action costs.

Experimental analysis: Overview

Solver	Solved	
	#	Time
CLASP	64	896.82
MINISAT	63	643.90
MINIMAXSAT	59	242.49
BSOLO	59	735.57
SAT4J	59	2028.22
CPLEX	57	3009.54
WMAXSATZ	54	2068.90
INCWMAXSATZ	52	559.62
SCIP	47	421.99
WBO	47	1032.60
AKMAXSAT	45	458.08
HYSAT	44	1865.66
MSUNCORE	39	728.30
GLPPB	23	2208.39

Table: We report the number of instances solved within the time limit ("#") and the total CPU time ("Time") spent on solved instances. Solvers are sorted according to the number of solved instances, and in case of a tie, according to CPU time.