A Reduction-Based Approach for Solving Disjunctive Temporal Problems with Preferences

Jean-Rémi Bourguet[1], Marco Maratea[2], Luca Pulina[1]

[1] POLCOMING, University of Sassari
[2] DIBRIS - University of Genova

AI*IA2013: Turin, Italy, December 4-6th 2013

Context

- Disjunctive Temporal Problems (DTPs) are an expressive formalism for temporal constraints modeling and processing
- DTPs are considered to be a good compromise between expressivity and efficiency: constraints are “limited” to (difference) constraints $l \leq x - y \leq u$, but the consistency of a set of such constraints is checked in polynomial time
- DTPs are useful for applications, especially in planning and scheduling

Disjunctive Temporal Problems with Preferences (DTPPs)

- DTPs are
  - finite conjunctions of DTP constraints; where
  - each DTP constraint is a finite disjunction of *difference constraint* of the form $l \leq x - y \leq u$, where x, y are arithmetic variables, and l, u are numeric constants.
- DTPPs extend DTPs with (piece-wise constant) preference functions defined over (soft) difference constraints.
- Given a DTPP ϕ, the goal is to find an assignment to the variables in ϕ that
  - satisfies hard DTP constraints, and
  - maximizes the sum of the preference values of satisfied soft DTP constraints
- Soft DTP constraints preference values need to be aggregated from the difference constraints preference values in it.

Approaches

- The state-of-the-art approach, implemented in the DTPP solver MAXILITIS, extends the approach of the DTP solver EPILITIS (Tsamardinos and Pollack, 2003), and
  - exploits the "max" semantic for aggregating preference values within DTP constraints: given a (candidate) solution, the preference value of a soft DTP constraint is defined to be the maximum value achieved by any of its satisfied disjuncts (Moffitt, 2011).
- We define an alternative approach that reduces DTPPs to Maximum Satisfiability of a set of Boolean combination of constraints of the form $l \bowtie x - y \bowtie u$, $\bowtie \in \{<, \leq\}$.

This approach extends our previous work (Maratea and Pulina, 2012) that dealt with constant preference functions.

Our reduction: Idea

Our reduction works as follows

- each hard DTP constraint remains unchanged in the resulting formula, while
- each soft DTP constraint is translated into a set of Boolean combination of constraints of the form $l \bowtie x - y \bowtie u$, $\bowtie \in \{<, \leq\}$, having
- proper weights assigned to the resulting constraints to adhere with the semantic of the problem.

Benchmarks

Random benchmarks

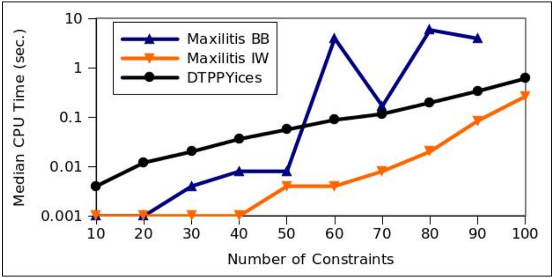
1. k disjuncts per DTP constraint
2. n arithmetic variables
3. m DTP constraints
4. l levels (preference values) in the piece-wise constant preference functions
5. all constants l, u are taken in $[-50, 100]$
6. all the preference values in w_{pc} are taken in $[1, 100]$

Setting in this paper...

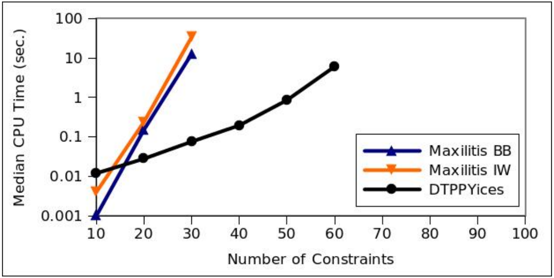
- for each tuple of values of the parameters, 10 instances are generated and then fed to the solvers
- the median of the CPUs is plotted
- DTPPYICES and two versions of MAXILITIS

Varying problem size

k=2, $m \in \{10, \ldots, 100\}$, n=0.8 $\times$ m, l=5



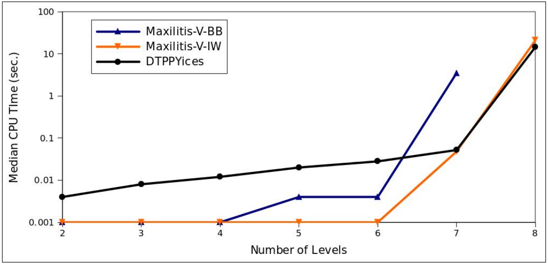
$w_{pc}(l) = l$ (Moffitt, 2011)



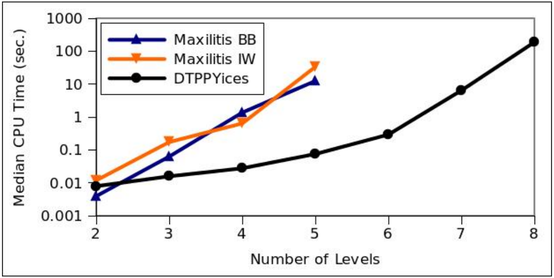
$w_{pc}(l) \in [1, 100]$

Varying preference levels

k=2, n=24, m=30, $l \in \{2, \ldots, 8\}$



$w_{pc}(l) = l$ (Moffitt, 2011)



$w_{pc}(l) \in [1, 100]$

Conclusions

In this work we have

- defined a reduction from DTPPs to Maximum Satisfiability of Boolean combination of constraints of the form $l \bowtie x - y \bowtie u$, $\bowtie \in \{<, \leq\}$
- implemented this reduction, using the SMT solver YICES as back-end solver
- run a (preliminary) experimental analysis against MAXILITIS

References

(Tsamardinos and Pollack, 2003) Ioannis Tsamardinos, Martha E. Pollack: Efficient solution techniques for disjunctive temporal reasoning problems. Artif. Intell. 151(1-2): 43-89 (2003)

(Pollack and Moffitt, 2005) Michael D. Moffitt, Martha E. Pollack: Partial Constraint Satisfaction of Disjunctive Temporal Problems. FLAIRS Conference 2005: 715-720

(Moffitt, 2011) Michael D. Moffitt: On the modelling and optimization of preferences in constraint-based temporal reasoning. Artif. Intell. 175(7-8): 1390-1409 (2011)

(Maratea and Pulina, 2012) Marco Maratea, Luca Pulina: Solving disjunctive temporal problems with preferences using maximum satisfiability. AI Commun. 25(2): 137-156 (2012)