

Modeling High School Timetabling (HSTT) as maxSAT/SMT

Emir Demirović, Nysret Musliu

Vienna University of Technology
Institute of Information Systems
Database and Artificial Intelligence Group

Motivation

- High school timetabling extremely popular
 - Every school does it!
- Significant difference between a good and a bad timetable.
- Time consuming, difficult and error prone to do by hand.
- Effects hundreds of students and teachers for prolonged periods of time.
- NP-complete.
- Natural connection between timetabling and logic.

High School Timetabling

- Consists of coordinating resources (teachers, rooms, students) with events (lessons).
- Covers over 16 different constraints, such as:
 - Evenly spreading lessons throughout the week.
 - Ensure each day is meaningful and balanced for students and teachers.
- Formulation (xHSTT) constantly evolving and covers variety of different educational systems.

MaxSAT

- $X_{e,t}$ - indicates whether an event e is taking place at time t .
 - Hard and soft HSTT constraints encoded into hard and soft clauses.
- $$\forall e \in E, t \in T, r \in R^e$$
- $$(X_{e,t} \rightarrow X_{e,t,r})$$
- Different (soft) cardinality constraints examined: Combinatorial, Sequential, Binary Adders, Cardinality Networks.

HSTT instance

Our Approach

HSTT to SAT/SMT encoder

SAT/SMT solver

SAT/SMT solution to final timetable

SMT

- Linear integer arithmetic
 - Modeled similarly as SAT.
- Bitvectors
 - Lesson \rightarrow Bitvector.
 - Bit \rightarrow Timeslot.
- HSTT constraints encoded through manipulations of bitvectors (add, and, or, shifts operations).

Time	9 AM	10 AM	11 AM	12 AM
Bitvec	0	0	1	1

Experiments

- Artificial and real-world instances from different countries.
- Solvers:
 - maxSAT: Sat4j-maxsat, optimax, WPM1, WPM2, ISAC, munsat.
 - SMT: Yices.
 - HSTT: GOAL – winner of ITC 2011.
- Approach: model as SAT/SMT, but also combine SAT/SMT with GOAL.

Results (24 h)

Instance	maxSAT	SMT	GOAL	SAT+GOAL
BrazilianInstance1	(0, 38)*	(0, 47)	(0, 54)	(0, 48)
BrazilianInstance2	(0, 32)	(0, 60)	(1, 42)	(0, 37)
BrazilianInstance4	(0, 205)	(0, x)	(16, 95)	(0, 142)
BrazilianInstance5	(0, 117)	(0, x)	(4, 121)	(0, 106)
BrazilianInstance6	(0, 230)	(0, x)	(4, 195)	(0, 171)
BrazilianInstance7	(0, 400)	(0, x)	(11, 230)	(0, 210)
SouthAfricaLewitt	(0, 0)*	(0, x)	(0, 18)	(0, 470)
SouthAfricaWoodlands	(0, 0)*	(-, -)	(2, 13)	(0, 71)
FinlandCollege	(0, 1523)	-	(1, 5)	(0, 14)
FinlandHighSchool	(0, 289)	-	(0, 14)	(0, 15)
FinlandSecondarySchool	(0, 252)	-	(0, 83)	(0, 85)
FinlandArtificalSchool	(0, 47)	-	(3, 6)	(0, 12)
GreecePatras2010	(0, 331)	-	(0, 0)*	(0, 0)*
GreeceWesternUni4	(0, 121)	-	(0, 5)	(0, 4)
GreeceHighSchool	(0, 0)*	(0, 0)*	(0, 0)*	(0, 0)*
KosovoInstance	(0, x)	-	(0, 5)	(0, 1059)
EnglandStPaul	(0, x)	-	(3, 48)	(0, 138)
ItalyInstance1	(0, 17)	(-, -)	(0, 19)	(0, 13)
ItalyInstance4	(0, 12825)	(-, -)	(0, 57)	(0, 59)

* - optimal solution; maxSAT: sat4j-maxsat; SMT - Yices

Conclusion

- Detailed formulation of HSTT as maxSAT and SMT.
- New complete methods for HSTT.
- maxSAT useful for HSTT
 - Competitive with GOAL, the winner of ITC 2011.
- SMT could potentially be useful, but needs to be further developed.
- Combining maxSAT with GOAL is a good direction.