

Online appendix for the paper
*Answer Set Programming as a Modeling Language
 for Course Timetabling*

published in Theory and Practice of Logic Programming

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submitted 10 April 2013; revised 23 May 2013; accepted 23 June 2013

Appendix A Further Experiments

A.1 Overview of a Web Portal for Curriculum-Based Course Timetabling

A web portal ¹ for the Curriculum-Based Course Timetabling (CB-CTT) problem has been actively maintained by the organizers of ITC-2007. The web site has provided a portfolio of formulations for the CB-CTT problem as defined in (Bonutti et al. 2012). The main features of this site are as follows:

- We can download problem instances both in `ectt` and XML formats and solutions dynamically uploaded by researchers. All instances are based on real data from various European universities.
- We can see some statistical indicators for each instance, such as conflict density, teachers' availability, rooms' suitability, lectures per day per curriculum, and room occupation.
- We can validate our solutions online and also download the source code of a solution validator written in C++.
- After registration, we can insert our solutions, lower bounds, instances, and links of interest for the timetabling community. It is noted that there is no time limitation for any method to find solutions and for any result to be entered into the CB-CTT web archives.

The best known bounds on the web have been obtained by various methods including the winner algorithm of ITC-2007, such as metaheuristics-based algorithms (Gaspero

¹ <http://tabu.diegm.uniud.it/ctt/>

Table A 1. *Benchmark results on EasyAcademy and Udine*

Instance	UD1		UD2		UD3		UD4		UD5	
	Best known	ASP	Best known	ASP	Best known	ASP	Best known	ASP	Best known	ASP
EA01	<i>n.a</i> >	55	<i>n.a</i> >	65	<i>n.a</i> >	120	<i>n.a</i> >	91	<i>n.a</i> >	1149
EA02	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	445	<i>n.a</i> >	184	<i>n.a</i> >	426
EA03	<i>n.a</i> >	1	<i>n.a</i> >	2	<i>n.a</i> >	164	<i>n.a</i> >	6936	<i>n.a</i>	<i>timeout</i>
EA04	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	18	<i>n.a</i> >	3235	<i>n.a</i> >	1238
EA05	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	14	<i>n.a</i> >	8	<i>n.a</i> >	99
EA06	<i>n.a</i> >*	5	<i>n.a</i> >*	5	<i>n.a</i> >	168	<i>n.a</i> >	240	<i>n.a</i> >	583
EA07	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	2404	<i>n.a</i> >	3884	<i>n.a</i>	<i>timeout</i>
EA08	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	88	<i>n.a</i> >	47	<i>n.a</i> >	146
EA09	<i>n.a</i> >*	2	<i>n.a</i> >*	4	<i>n.a</i> >	40	<i>n.a</i> >	22	<i>n.a</i> >	70
EA10	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	1585	<i>n.a</i> >	635	<i>n.a</i> >	1558
EA11	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	114	<i>n.a</i> >	31	<i>n.a</i> >	157
EA12	<i>n.a</i> >*	2	<i>n.a</i> >*	4	<i>n.a</i> >	50	<i>n.a</i> >	26	<i>n.a</i> >	167
Udine1	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	886	<i>n.a</i> >	366	<i>n.a</i> >	995
Udine2	<i>n.a</i> >*	4	<i>n.a</i> >*	8	<i>n.a</i> >	228	<i>n.a</i> >	222	<i>n.a</i> >	576
Udine3	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	83	<i>n.a</i> >	106	<i>n.a</i> >	369
Udine4	<i>n.a</i> >	37	<i>n.a</i> >	84	<i>n.a</i> >	24	<i>n.a</i> >	57	<i>n.a</i> >	206
Udine5	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	298	<i>n.a</i> >	157	<i>n.a</i> >	387
Udine6	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	110	<i>n.a</i> >	68	<i>n.a</i> >	152
Udine7	<i>n.a</i> >*	0	<i>n.a</i> >*	0	<i>n.a</i> >	88	<i>n.a</i> >	48	<i>n.a</i> >	80
Udine8	<i>n.a</i> >	17	<i>n.a</i> >	31	<i>n.a</i> >	228	<i>n.a</i> >	233	<i>n.a</i> >	569
Udine9	<i>n.a</i> >*	18	<i>n.a</i> >*	21	<i>n.a</i> >	45	<i>n.a</i> >	41	<i>n.a</i> >	343

and Schaerf 2003; Gaspero and Schaerf 2006; Clark et al. 2008; Lü and Hao 2010; Geiger 2012; Abdullah et al. 2012), integer programming (Lach and Lübbecke 2012), SAT/MaxSAT (Achá and Nieuwenhuis 2012), and hybrid approach (Müller 2009). However, as can be seen on the web, each method has strength and weakness, and it is difficult to develop a universal timetabling solver which can efficiently solve a wide range of CB-CTT instances with different formulations at present.

A.2 Experimental Results on New Benchmark Sets

Very recently two new benchmark sets have been added to the web site mentioned above. One is **EasyAcademy** consisting of 12 instances denoted by EA* from various Italian universities. Another is **Udine** consisting of 9 real-world instances denoted by Udine* from the school of Engineering of University of Udine. We note that there are no solutions available on the web before.

To further evaluate the efficiency of our proposed full encodings, we carry out experiments on those new benchmark sets in the same environment as in Section 6. We solved 21 instances as optimization problems with five different formulations UD1–UD5. We set a timeout of 3 hours for each.

Table A 1 shows the best upper bounds obtained by our encoding. For the tested 105 combinations, our encoding was able to give upper bounds for 103 combinations. Furthermore, in the case of UD1 and UD2, it succeeded in finding new optimal solutions for 34 combinations (80% in the tested 42 combinations).

However, our encoding was not able to give any feasible solutions in timeout for the instances EA03 and EA07 with UD5. The cause of this issue turned out to be our ASP encoding of the soft constraint S_7 for **TravelDistance** in Fig. 7. This is because these two instances have greater number of rooms located in different buildings than the others. For example, EA03 consists of 145 courses, 65 rooms in 9 different buildings, 65 curricula,

3207 unavailability constraints, and 1350 room constraints. The resulting file size after grounding is 7.9 GB. It is noted that it is 70 MB if we leave S_7 out of our encoding, and we can easily find a feasible solution of EA03. To overcome this issue, we might be able to apply two-stage optimization strategy used in integer programming (Lach and Lübbecke 2012) to our approach.

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