
Real-world university course timetabling at the



International
Timetabling
Competition 2019

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ORTEC



Educational timetabling competitions supported by PATAT

ITC 2002

- events, rooms, students
- enrollment-based timetabling
 - students in events cannot have any overlap

ITC 2007

- examination timetabling
- post enrolment-based course timetabling
 - ITC 2002 extension
- curriculum-based course timetabling
 - based on real-world instances from University of Udine

ITC 2011

- high-school timetabling
 - real-world instances

Real-world problems taken from the educational scheduling system UniTime



- Enrollment-based timetabling
 - students enroll in courses
- Hierarchical course structure how to split course into events/classes
 - students sectioning often needed
 - student sectioning must respect the course structure

	Limit	Date Pattern	Time Pattern	---Preferences---		-----Timetable-----	
				Time	Room	Time	Room
IT 200	100	Software engineering					
Lecture	100	Full Term	3h				
Recitation	100	Full Term	1h				
Laboratory	100	Full Term	2h		Computer		
Lec 1	100	Full Term	3h			Th 8:25a-11:00a	Y 1
Rec 1	50	Full Term	1h			M 11:10a-11:55a	A 60
Lab 1	25	Full Term	2h		Computer	Th 4:40p-6:20p	D 28
Lab 2	25	Full Term	2h		Computer	Th 2:50p-4:30p	D 28
Rec 2	50	Full Term	1h			W 1:55p-2:40p	A 60
Lab 3	25	Full Term	2h		Computer	Th 1:00p-2:40p	D 28
Lab 4	25	Full Term	2h		Computer	Th 11:10a-12:50p	D 28

 Required

 Strongly Preferred

 Preferred

 Neutral

 Discouraged

 Strongly Discouraged

 Prohibited

- Time placement for classes
 - week pattern: required weeks
 - full term: weeks="111111111111"
 - day pattern: required days of week
 - Monday: days="1000000"
 - start time period and length using 5 minutes periods
 - 7:00–8:00: start="84" length="12"
 - each possible placement specified with penalties



Required



Strongly Preferred



Preferred



Neutral



Discouraged



Strongly Discouraged



Prohibited

- course → classes → meetings
 - MW 7:30–8:20 even weeks
days="1010000"
start="90" length="10"
weeks="0101010101010"

- Rooms
 - capacity
 - unavailable periods
 - travel times matrix
 - students must be able to attend their classes when they are at different locations
- Room placement for classes
 - each possible placement specified with penalties

Constraint	Opposite	Time	Days	Weeks	Room	Pairs
SameStart		✓	-	-	-	✓
SameTime	DifferentTime	✓	-	-	-	✓
SameDays	DifferentDays	-	✓	-	-	✓
SameWeeks	DifferentWeeks	-	-	✓	-	✓
SameRoom	DifferentRoom	-	-	-	✓	✓
Overlap	NotOverlap	✓	✓	✓	-	✓
SameAttendees		✓	✓	✓	✓	✓
Precedence		✓	✓	✓	-	✓
WorkDay(S)		✓	✓	✓	-	✓
MinGap(G)		✓	✓	✓	-	✓
MaxDays(D)		-	✓	-	-	days over D
MaxDayLoad(S)		✓	✓	✓	-	slots over S
MaxBreaks(R,S)		✓	✓	✓	-	breaks over R
MaxBlock(M,S)		✓	✓	✓	-	blocks over M

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For classes in parent-child relationship: **SameAttendees**

- some institutions may replace it by **NotOverlap**

For classes in the same subpart: **NotOverlap**

- some institutions may remove it

- Assignment of **times and rooms to classes**
- **Optimization** by minimizing penalties of
 - time placement
 - room placement
 - violated soft distribution constraints
 - student conflicts
 - two classes overlap in time or
 - are close to each other in rooms that are too far apart

- Data from the UniTime educational scheduling system
 - Europe
 - Masaryk University 
 - AGH University of Science and Technology 
 - North and South America
 - Purdue University 
 - Maryville University 
 - Universidad Yachay Tech 
 - Asia
 - Lahore University of Management Sciences 
 - İstanbul Kültür University 
 - Turkish-German University 
 - Bethlehem University 
 - Africa
 - University of Nairobi 

7 out of 10 faculties use UniTime: separated problems

Faculty of Informatics

muni-fi problems

- classical middle-size problem
 - 35 rooms
 - 500–600 classes
 - 1,500–1,700 students (more in fall semesters)
 - 10 classes per student
- simple course structure
 - lecture, seminars, 1 lecture + seminars
- classes once a week two hours typically
- one building mostly
- even/odd weeks classes
- pre-enrollment \Rightarrow rather high conflicts (550–680)
- single timetable manager

Faculty of Sport Studies: present study

muni-fsps-spr17

- 40 rooms, 550 classes, 850 students, 12 classes per student
 - solved optimally
- many buildings: travel times
small utilization – partially used sport facilities
- simple course structure
 - lecture, seminars, 1 lecture + seminars
- enrollments constructed from rigid curricula
 - 0–5 conflicts
- high number of weeks: 19
 - timetabling of sports for whole university during examination period as well
 - however: students from the Faculty of Sport Studies only
- single timetable manager

Faculty of Sport Studies: distance learning

muni-fsps-spr17c

- irregular timetable each Friday
 - one course split to single day classes using `DifferentWeeks`
- 14 weeks
- 30 rooms, 650 classes, 400 students, 33 classes per student
 - gap 48 %

Faculty of Sport Studies: distance learning + present study

muni-fspsx-fal17

- 21 weeks
- 30 rooms, 1,600 classes, 1,150 students, 22 classes per student
 - gap 26 %

Faculty of Education: present study

muni-pdf-spr16

- 80 rooms, 1,500 classes, 3,450 students
 - pairs of curricula for each student
 - Math-Physics, English-History, Physics-Music, ...
 - resulting in more student conflicts than "classical" curricula but less than pre-enrollments
 - data input by several departmental managers
 - more diversified input
- timetabling by single timetable manager
- non-binarized distribution constraints MaxDayLoad, MaxBlock

More complex and larger problems

Faculty of Education: distance learning

muni-pdf-spr16c

- irregular timetable each Friday and Saturday
 - one course split to single day classes using `DifferentWeeks`
 - 13 weeks: *different timetable* for each or $2*13$ days for 13 weeks
- 70 rooms, 2,500 classes, 2,900 students
140 minutes per meeting (present study: 85)
- partially included classes from present study
 - many courses have two configurations: distance learning, present study
 - distance learning solved on top of the timetable from present study
 - classes from present study fixed (1,100 out of 2,500 classes)

Faculty of Education: distance learning + present study

muni-pdfx-fall17

- 90 rooms, 3,700 classes, 5,650 students
130 minutes per meeting

- **Separate timetable for each faculty** agh problems
 - 40–80 rooms, 450–1,850 classes, 1,600–2,250 students
 - shared resources between faculties, students from different faculties
 - Faculty of Humanities: 73% of classes for outside students
- **Large-scale problem for the whole university** included agh-fal17
 - 330 rooms, 5,100 classes, 7,000 students
- **Rigid curricula** with mandatory and elective courses only

- **Coordinated timetabling process** pu problems
pu-llr-spr17
 - shared large lecture room timetabling
 - 75 rooms, 1,000 classes, 27,000 students, 3 classes per student
very high utilization
 - solved optimally
 - school and departmental timetabling
 - shared computer laboratories
 - changes: complete problem
- Problems from several (5/9) and all departments: huge problems
 - 80/220/770 rooms, 1,050/2,800/8,800 classes 13,500/35,000/38,500 stud.
- Rich **course structure**
 - introductory Biology for most freshmen
- **Class several times a week at the same time and room**
 - Monday, Wednesday, Friday at 7:30 am, 8:30 am, ... 4:30 pm
- **Last-like semester enrollments**
- Buildings at campus: **travel times**

Students by distribution constraints SameAttendees/NoOverlap

- SameAttendees takes care of travel times

Turkish-German University, Turkey

tg problems

- small problems: 15 rooms, 700 classes
- visiting lecturers from Germany coming for a short time
- solved optimally
 - 72,000–79,000 hard class pairs

İstanbul Kültür University, Turkey

iku problems

- 210 rooms, 2,600–2,800 classes

Lahore University of Management Sciences, Pakistan

lums problems

- 70 rooms, 500–1,100 classes
- multiple days for class: 1.8 per class

- Asia: **Bethlehem University, Palestine** bet problems
- 60 rooms, 1,000–1,100 classes, 2,900–3,000 students
 - multiple days for classes: 1.3 days per class
 - high utilization
 - non-binarized distribution constraints MaxBlock, MaxDays
- North America: **Maryville University, USA** mary problems
- about 900 classes, 90 rooms, 3,500–5,000 students, 1.5 days per class
 - simple course structure: lecture, seminars, 1 lecture + seminars
- South America: **Universidad Yachay Tech, Ecuador** yach-fal17
- 400 classes, 30 rooms, 800 students
- Africa: **University of Nairobi, Kenya** nbi-spr18
- 800 classes, 70 rooms, 2,300 students

Position	Team	Early	Middle	Late	Total points
1.	Holm et al.	99	150	240	489
2.	Rappos et al.	72	94	156	322
3.	Gashi et al.	41	85	147	273
4.	Er-rhaimini	36	71	145	252
5.	Lemos et al.	17	32	30	79

Position	Author	Early	Middle	Late	Total points
1.	Dennis Holm	96	130	236	462
2.	Tomáš Müller	63	119	186	368
3.	Efstratios Rappos	57	60	123	240
4.	Edon Gashi	19	53	98	170
5.	Karim Er-rhaimini	16	41	92	149
6.	Alexandre Lemos	10	27	99	136
7.	I Gusti Agung Premananda	3	27	62	92
8.	Jason C.H.	2	10	40	52
9.	Marlúcio Alves Pires	6	15	22	43
10.	Henrik Sejer Pedersen	10	10	23	43
11.	Georgia Ioanna Makraki	0	3	10	13
12.	Eduardo Flores	0	3	1	4
13.	Jerry Wang	1	2	0	3
14.	Matthew Davison	0	0	2	2

- Almost 400 registered users from 60 countries
- 16 users uploaded one or more solutions of competition instances
- 25 users uploaded one or more solutions of competition or sample instances
- 44 users successfully validated one or more solutions

- **MIP, matheuristic**: Dennis S. Holm, Rasmus Ø. Mikkelsen, Matias Sørensen, Thomas R. Stidsen
 - MaCom / Technical University of Denmark, Denmark
- **MIP, matheuristic**: Efstratios Rappos, Eric Thiémard, Stephan Robert, Jean-François Hêche
 - HEIG-VD, Switzerland
- **Simulated annealing**: Edon Gashi, Kadri Sylejmani
 - University of Prishtina, Kosovo
- **MaxSAT**: Alexandre Lemos, Pedro T Monteiro, Inês Lynce
 - INESC-ID / IST, Universidade de Lisboa, Portugal
- **UniTime**: Tomáš Müller
 - Purdue University, USA



Conference on the Practice and Theory
of Automated Timetabling (PATAT)



ORTEC: optimization software and
analytics solutions



Apereo Foundation: supporting open-source
software for higher education



EURO working group on Automated Timetabling
(EWG PATAT)



UniTime educational scheduling system



Faculty of Informatics, Masaryk University