Real-world university course timetabling at the

International Timetabling Competition 2019

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International Timetabling Competitions

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
Hierarchical course structure

<table>
<thead>
<tr>
<th>Course</th>
<th>Limit</th>
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<th>Room</th>
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<td>D 28</td>
</tr>
</tbody>
</table>

Legend:
- **Required**
- **Strongly Preferred**
- **Preferred**
- **Neutral**
- **Discouraged**
- **Strongly Discouraged**
- **Prohibited**
Time placement

- **Time placement for classes**
  - **week pattern**: required weeks
    - full term: weeks="1111111111111"
  - **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**

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

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Room placement

- **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
### Distribution constraints on set of classes

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<tr>
<th>Constraint</th>
<th>Opposite</th>
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<th>Days</th>
<th>Weeks</th>
<th>Room</th>
<th>Pairs</th>
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</tr>
</tbody>
</table>

- Time: Incompatible
- Days: Incompatible
- Weeks: Incompatible
- Room: Incompatible
- Pairs: Incompatible

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## Course structure & generated distr. constraints

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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
Solution & optimization criteria

- 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
Real-world data instances

- 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
Europe: Masaryk University, Czech Republic

7 out of 10 faculties use UniTime: separated problems

Faculty of Informatics

- 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 ⇒ rather high conflicts (550–680)

- single timetable manager
Faculty of Sport Studies: present study

- 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

- 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

- 21 weeks

- 30 rooms, 1,600 classes, 1,150 students, 22 classes per student
  - gap 26%
Faculty of Education: present study

- 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
Europe: Masaryk University, Czech Republic

More complex and larger problems

Faculty of Education: distance learning

- 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

- 90 rooms, 3,700 classes, 5,650 students
- 130 minutes per meeting
Separate timetable for each faculty
- 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
- 330 rooms, 5,100 classes, 7,000 students

Rigid curricula with mandatory and elective courses only
USA: Purdue University

- Coordinated timetabling process
  - 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
Universities from Asia

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
Remaining universities

Asia: Bethlehem University, Palestine
- 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
- 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
- 400 classes, 30 rooms, 800 students

Africa: University of Nairobi, Kenya
- 800 classes, 70 rooms, 2,300 students
## Competition results

<table>
<thead>
<tr>
<th>Position</th>
<th>Team</th>
<th>Early</th>
<th>Middle</th>
<th>Late</th>
<th>Total points</th>
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Current status

- 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
Presentations and solutions for ITC 2019

- **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
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UniTime educational scheduling system

Faculty of Informatics, Masaryk University