Rapid Development of University Course Timetables

Hana Rudová* Tomáš Müller°

*Faculty of Informatics, Masaryk University
Brno, Czech Republic
hanka@fi.muni.cz

°Purdue University
West Lafayette, USA
muller@unitime.org

MISTA 2011

UniTime

http://www.unitime.org

Complex university timetabling system

- course timetabling
- examination timetabling
- event timetabling
- student scheduling
  - under development

Primary development for Purdue University

- applied since 2005
- decentralized coordinated timetabling for 40,000 students

Applied and extended for other institutions: Masaryk University

- Faculty of Arts: 10,800 students, 1,570 courses, 49 rooms
  - generated timetables published 8 weeks after the first meeting with schedule manager
- Faculty of Education: 10,000 students, 2 timetabling problems

Model of Timetabling Problem in UniTime

Course structure

- course = set of classes
- students can be split between some classes
  - example: groups for seminaries
- students can visit several classes a week
  - example: several lectures a week

	Demand	Mins Per Week	Limit	Manager	Date Pattern	Time Pattern	Preferences: Time	Preferences: Room	Preferences: Distribution	Instructor
M E 263 M E 263H	98		96							
Lecture		150	96	LLR	Full Term	3 x 50 2 x 75		WTHR Computer		
Recitation		100	96	M E	Full Term	2 x 50		ME 120 ME 236 Classroom		
Laboratory		50	84-120	LAB	Even Wks	1 x 50		Windows XP		
Lec 1		150	96	LLR	Full Term	3 x 50 2 x 75		WTHR Computer		**J. Smith** C. Bing
Rec 1		100	48	M E	Full Term	2 x 50		ME 120 ME 236 Classroom	Back-To-Back M E 263 Rec 1 M E 263 Rec 2	**J. Novak**
Lab 1		50	14-20	LAB	Even Wks	1 x 50		Windows XP		
Lab 2		50	14-20	LAB	Even Wks	1 x 50		Windows XP		
Lab 3		50	14-20	LAB	Even Wks	1 x 50		Windows XP		
Rec 2		100	48	M E	Full Term	2 x 50		ME 120 ME 236 Classroom	Back-To-Back M E 263 Rec 1 M E 263 Rec 2	**J. Novak**
Lab 4		50	14-20	LAB	Odd Wks	1 x 50		Windows XP		
Lab 5		50	14-20	LAB	Odd Wks	1 x 50		Windows XP		

Model of Timetabling Problem in UniTime

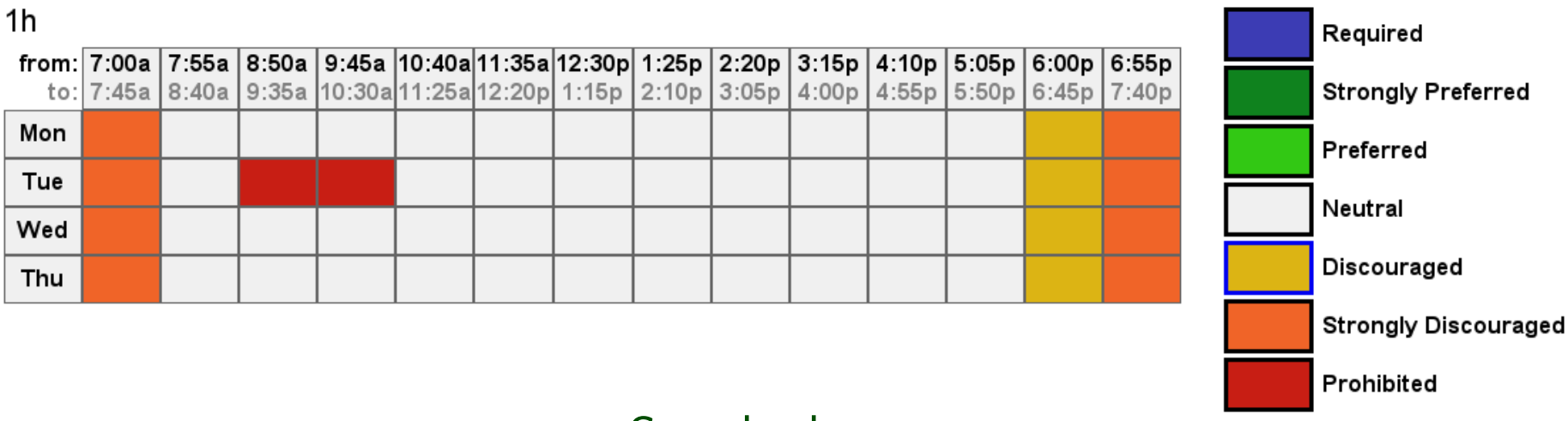
Constraint satisfaction problem

- domain variable = class
- domain of class = possible placements in timetable
- hard constraints
  - requirements on time and room placement of class
  - resource contraints: room, teacher
  - requirements on placement of groups of classes

Model of Timetabling Problem in UniTime

Soft constraints = weighted constraints = optimization criteria

- preferences on time and room placement of classes
- preferences on placement of groups of classes
- classes of one student should not overlap
  - enrollment-based timetabling
  - student conflicts minimization



Standard room

A 51

A – Poříčí 9

Timetabling Process

Initial timetabling

- automated generation of initial timetable
- Iterative forward search
  - constructive algorithm
  - subsequent extension of consistent timetable by other classes
  - no constraint propagation

Interactive timetabling

- subsequent modification of classes by schedule deputies
- Repair branch and bound
  - applied on existing solution
  - removal of one class and finding its new placement
  - upper bound: at most N classes can be moved at the same time
    - typically: N=2

Interactive Timetabling

Suggestions

Score	*Class*	*Date*	*Time*	*Room*	*Students*
+47	PSY 120 Lec 5	Full Term	MWF 7:30a	WTHR 200 → CL50 224	0
+104.6	PSY 120 Lec 5	Full Term	MWF 7:30a	WTHR 200 → LILY 1105	+32
	AGEC 217 Lec 3	Full Term	MWF 7:30a	LILY 1105 → CL50 224	
+107.725	PSY 120 Lec 5	Full Term	MWF 7:30a → MWF 4:30p	WTHR 200 → EE 129	+73
	ECE 270 Lec 1	Full Term	MWF 4:30p	EE 129 → FRNY G140	
+111.7	PSY 120 Lec 5	Full Term	MWF 7:30a → MWF 2:30p	WTHR 200 → EE 129	+115
	MA 261 Lec 3	Full Term	MWF 2:30p → MWF 7:30a	EE 129 → PHYS 114	
+111.7	PSY 120 Lec 5	Full Term	MWF 7:30a → MWF 2:30p	WTHR 200 → EE 129	+115
	MA 261 Lec 3	Full Term	MWF 2:30p → MWF 7:30a	EE 129 → PHYS 112	

(all 2037 possibilities up to 2 changes were considered, top 5 of 13 suggestions displayed) Search Deeper

Selected Publications

Rudová and Murray.
University course timetabling with soft constraints.
PATAT, LNCS 2740, 2003.

Müller.
Constraint-based Timetabling
Ph.D. thesis, Charles University, 2005.

Rudová, Müller, and Murray.
Complex university course timetabling.
Journal of Scheduling, 14(2): 187-207, Springer, 2011.

Faculty of Arts

Timetables generated by UniTime for Spring 2011 and Fall 2011

- initial timetabling & interactive timetabling

Fall 2010: manual solution

- partial timetables created by 44 departmental schedule deputies
  = input for the central schedule manager creating the timetable

Spring 2011

- the number of available classrooms decreased from 65 to 49
- timetable necessary within 8 weeks

- training of 44 schedule deputies infeasible due time horizon
- manually created partial timetables as the primary input
- other data from Information System of Masaryk University

Input Data

Partial timetables

- MS Excel tables
  - same as before automated timetabling
- time assignment for all classes
- room assignment for 69 % of classes
- designated teachers for classses
- preferred room equipment
  - only extension of MS Excel tables
  - standard room, multi-media lab, computer lab

Input Data

Partial timetables

- MS Excel tables
  - same as before automated timetabling
- time assignment for all classes
- room assignment for 69 % of classes
- designated teachers for classses
- preferred room equipment
  - only extension of MS Excel tables
  - standard room, multi-media lab, computer lab

Information System

- 49 rooms: identifier, building, capacity, equipment
- 584 teachers
- 1,570 courses
- 70,689 last-like semester enrollments (course, student)

Course Structure

	Last Enrollment	Limit	Room Ratio	Manager	Date Pattern	Mins Per Week	Time Pattern	----Preferences---- Time	Room Distribution
BJ BJA100	**0**	100		**Jazykový kurz I**					
AJ AJ01000				Jazykový kurz					
Přednáška		100		FF	Každý týden	50			
Seminář		100		FF	Každý týden	100			
Před 1		100	0.90	FF	Každý týden	50	1h		G G22 G MULT
Sem 1		50		FF	Každý týden	100	2h		G G21 G POČ
Sem 2		50		FF	Každý týden	100	2h		G G21 G POČ

Cross list

Classes

Course Constraints

Cross-lists identification

- based on partial timetable: automatically
- remaining: manually
- 1,570 $\rightarrow$ 1,421 courses

Classes

- 1,917 $\rightarrow$ 1,746 classes
- students of course
  - split among classes: much more common – automatically
  - share among classes: entered manually

Goals

Assign times and rooms to all classes

Optimization criteria

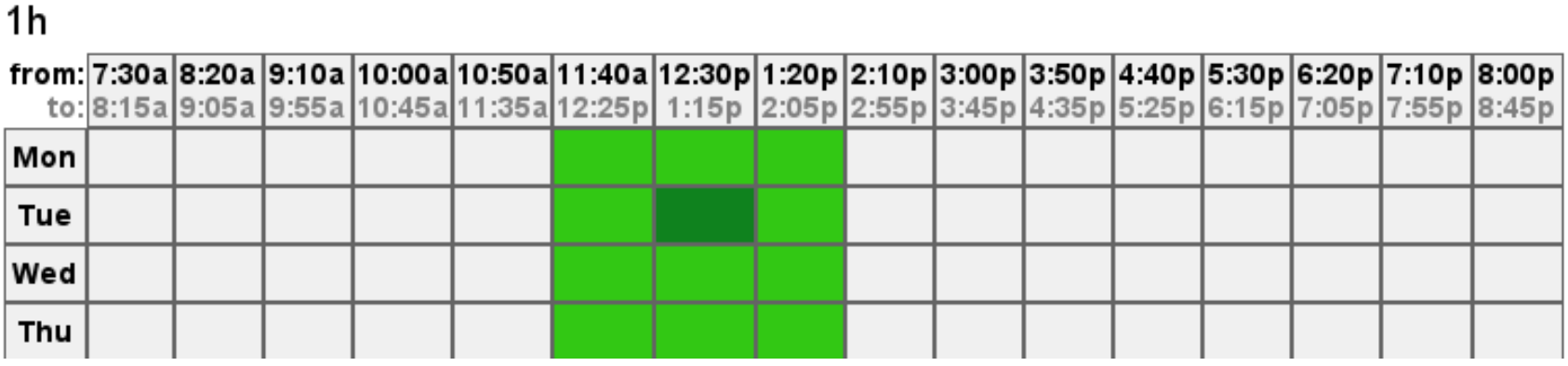
- student conflicts minimization
  - last-like enrollment data
- room equipment preferences
  - all classes: standard room, multi-media lab, computer lab
- building preferences = keep selected building of room
  - 69 % of classes: preferred building in UniTime
- room selection preferences = keep selected room
  - 69 % of classes: strongly preferred room in UniTime

Standard room
A – Poříčí 9
A 51

Goals (continues)

For all classes

- time preferences = keep selected time
  - UniTime: selected time strongly preferred
    one period before and after selected time preferred



Goals (continues)

For all classes

- time preferences = keep selected time
  - UniTime: selected time strongly preferred
    one period before and after selected time preferred

1h

from: / to:	7:30a 8:15a	8:20a 9:05a	9:10a 9:55a	10:00a 10:45a	10:50a 11:35a	11:40a 12:25p	12:30p 1:15p	1:20p 2:05p	2:10p 2:55p	3:00p 3:45p	3:50p 4:35p	4:40p 5:25p	5:30p 6:15p	6:20p 7:05p	7:10p 7:55p	8:00p 8:45p
Mon																
Tue																
Wed																
Thu																

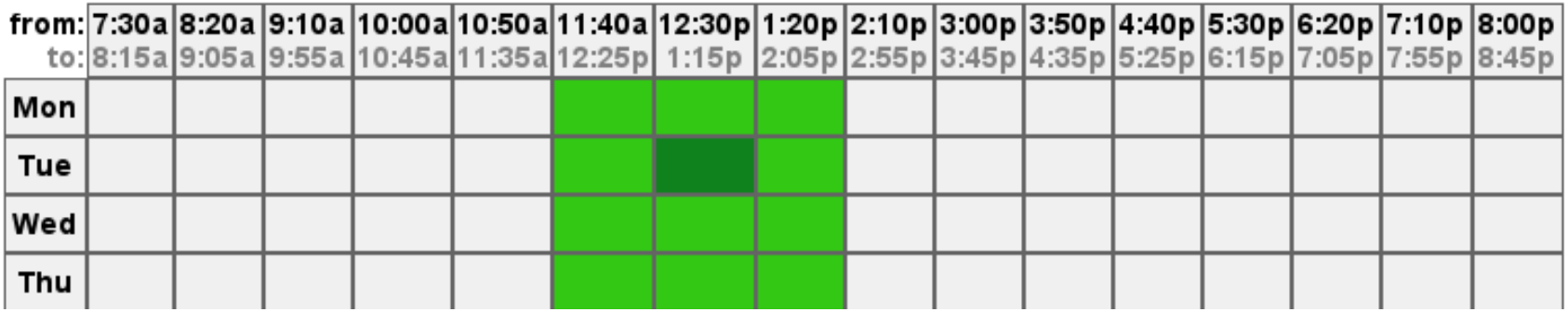
- discouradge early and late times
  - due to renovation times extended from 7:30 am to 8:45 pm
  - UniTime: default preferences for all classes

Goals (continues)

For all classes

- time preferences = keep selected time
  - UniTime: selected time strongly preferred
    one period before and after selected time preferred

1h



- discouradge early and late times
  - due to renovation times extended from 7:30 am to 8:45 pm
  - UniTime: default preferences for all classes

Summary

- missing initial room assignment for 31 % of classes
- for 48 % of classes: initial placement infeasible

Results for Spring 2011

Solution	Fully automated	First published	Finalized
Selected time kept (%)	89.8	89.9	87.66
Selected room kept (%)	62.9	65.6	64.05

Results for Spring 2011

Solution	Fully automated	First published	Finalized
Selected time kept (%)	89.8	89.9	87.66
Selected room kept (%)	62.9	65.6	64.05
Student conflicts	812	871	1,119
Time preferences (%)	92.34	92.53	89.20
Room preferences (%)	82.99	83.38	74.65

Results for Spring 2011

Solution	Fully automated	First published	Finalized
Selected time kept (%)	89.8	89.9	87.66
Selected room kept (%)	62.9	65.6	64.05
Student conflicts	812	871	1,119
Time preferences (%)	92.34	92.53	89.20
Room preferences (%)	82.99	83.38	74.65
Broken hard constraints	0	10	71
Interactive time changes (%)	-	1.4	10.85
Interactive room changes (%)	-	6.7	20.95

Similar results for Fall 2011

Conclusion & Future Work

Faculty of Arts: Spring 2011

- harder problem due to building renovations
- schedule manager evaluated her workload to 30 %
- work done on problem analysis and data conversions
- UniTime: no work on constraint solver, few minor changes in GUI

Conclusion & Future Work

Faculty of Arts: Spring 2011

- harder problem due to building renovations
- schedule manager evaluated her workload to 30 %
- work done on problem analysis and data conversions
- UniTime: no work on constraint solver, few minor changes in GUI

Faculty of Arts: Fall 2011

- surprizingly no work on analysis, conversions and UniTime

Conclusion & Future Work

Faculty of Arts: Spring 2011

- harder problem due to building renovations
- schedule manager evaluated her workload to 30 %
- work done on problem analysis and data conversions
- UniTime: no work on constraint solver, few minor changes in GUI

Faculty of Arts: Fall 2011

- surprizingly no work on analysis, conversions and UniTime

Research challenges

- effective combination of various criteria (soft constraints)
- teacher timetables
  - compact vs. spread, unpopular times vs. fairness, lunches, too many hours, ...

Data entry by all 44 schedule deputies

Faculty of Education: Fall 2011

- Similar problem size
- More time for solution
- Data entry by 40 schedule deputies

Faculty of Education: Fall 2011

- Similar problem size
- More time for solution
- Data entry by 40 schedule deputies
- Curriculum-based timetabling
  - compulsory courses with almost no overlaps
    - about 100 student conflicts among 1,500 classes
  - optional courses with possibly higher overlaps
    - about 300 additional student conflicts for 250 additional classes
      mostly conflicts between a compulsory and an optional class
- Teacher and curriculum timetables

Faculty of Education: Fall 2011

- Similar problem size
- More time for solution
- Data entry by 40 schedule deputies
- Curriculum-based timetabling
  - compulsory courses with almost no overlaps
    - about 100 student conflicts among 1,500 classes
  - optional courses with possibly higher overlaps
    - about 300 additional student conflicts for 250 additional classes
      mostly conflicts between a compulsory and an optional class
- Teacher and curriculum timetables
- Combined study with work
  - timetabling of Fridays & Saturdays
  - each course: up to 6 meetings at different times
  - each of 2,200 meetings: about 300×30 possible placements!
    - 12 weeks, 2 days, 12.5 possible times, 30 rooms