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System Demonstration of

Interactive Course Timetabling

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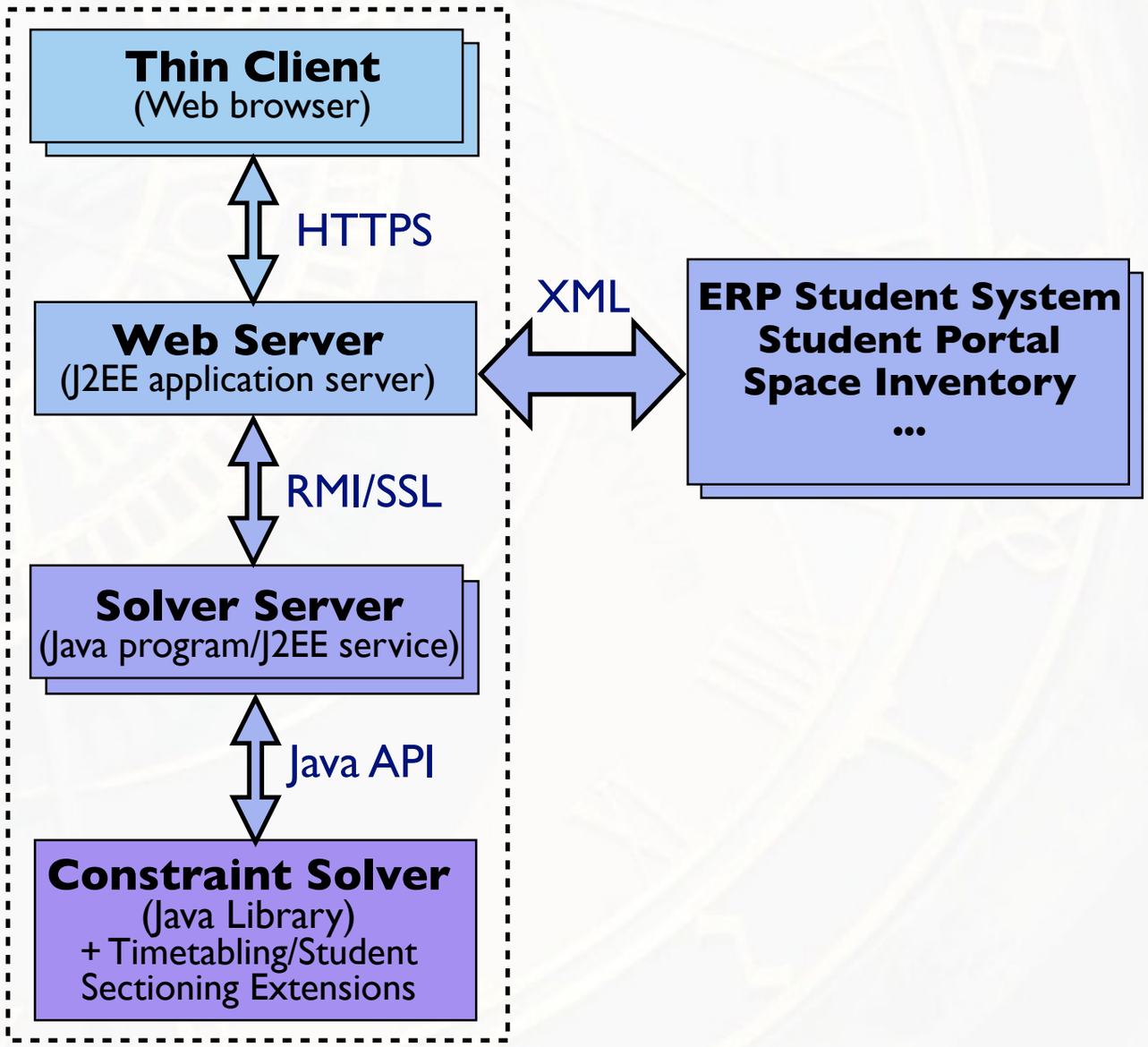
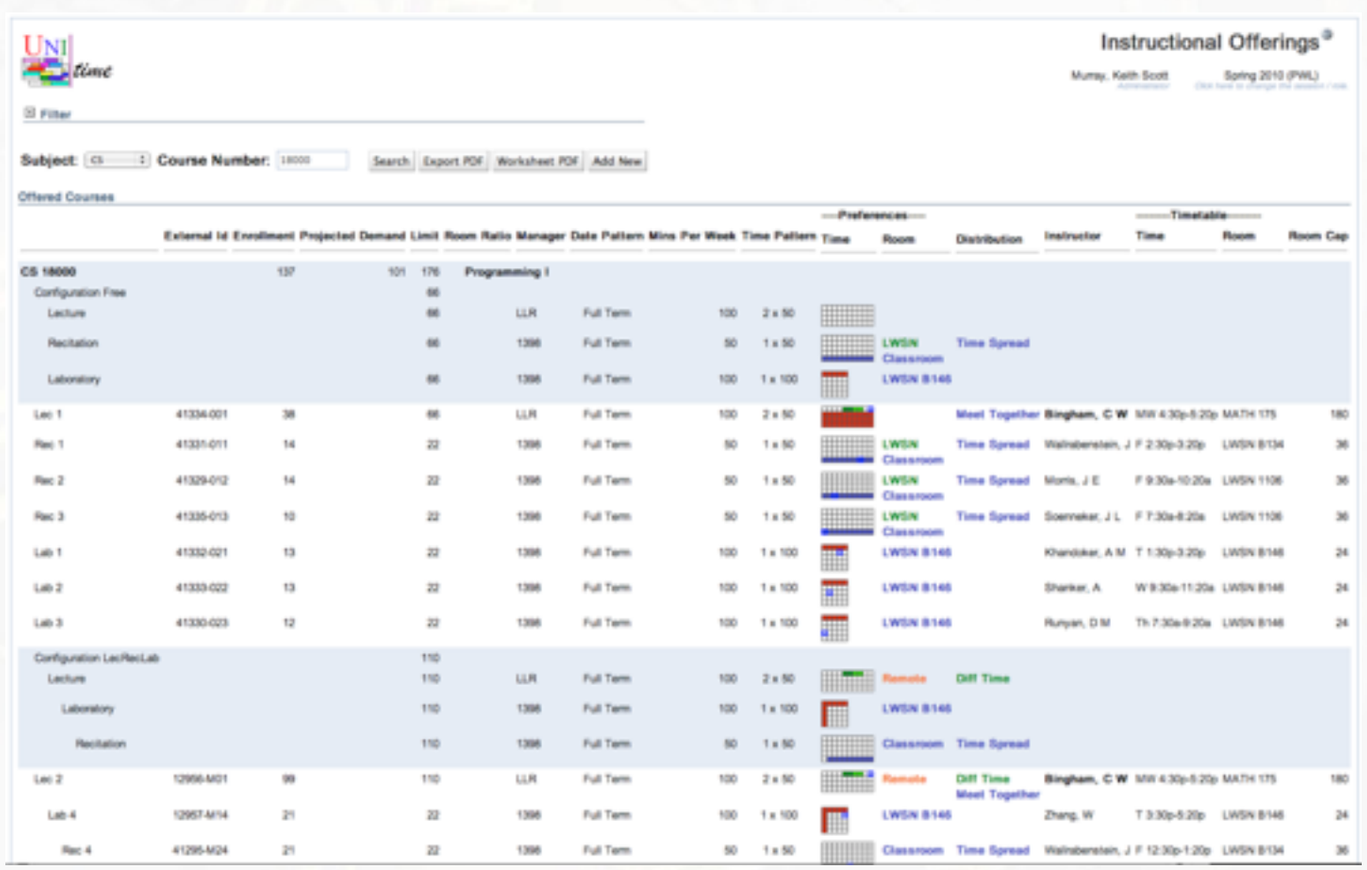
System Highlights

- Publicly available
  - Open Source License (GNU GPL for interface, LGPL for solver)
  - Resources available online at www.unitime.org
- Client-server architecture
  - Web-based interface
  - Using JSP, Struts, Hibernate, GWT
  - Compatible with Firefox, IE, Safari, and Chrome
- Platform independent
  - Java, Tomcat, Oracle/MySQL
- Extensible & customizable
  - Applicable to a variety of university timetabling problems
  - XML interfaces



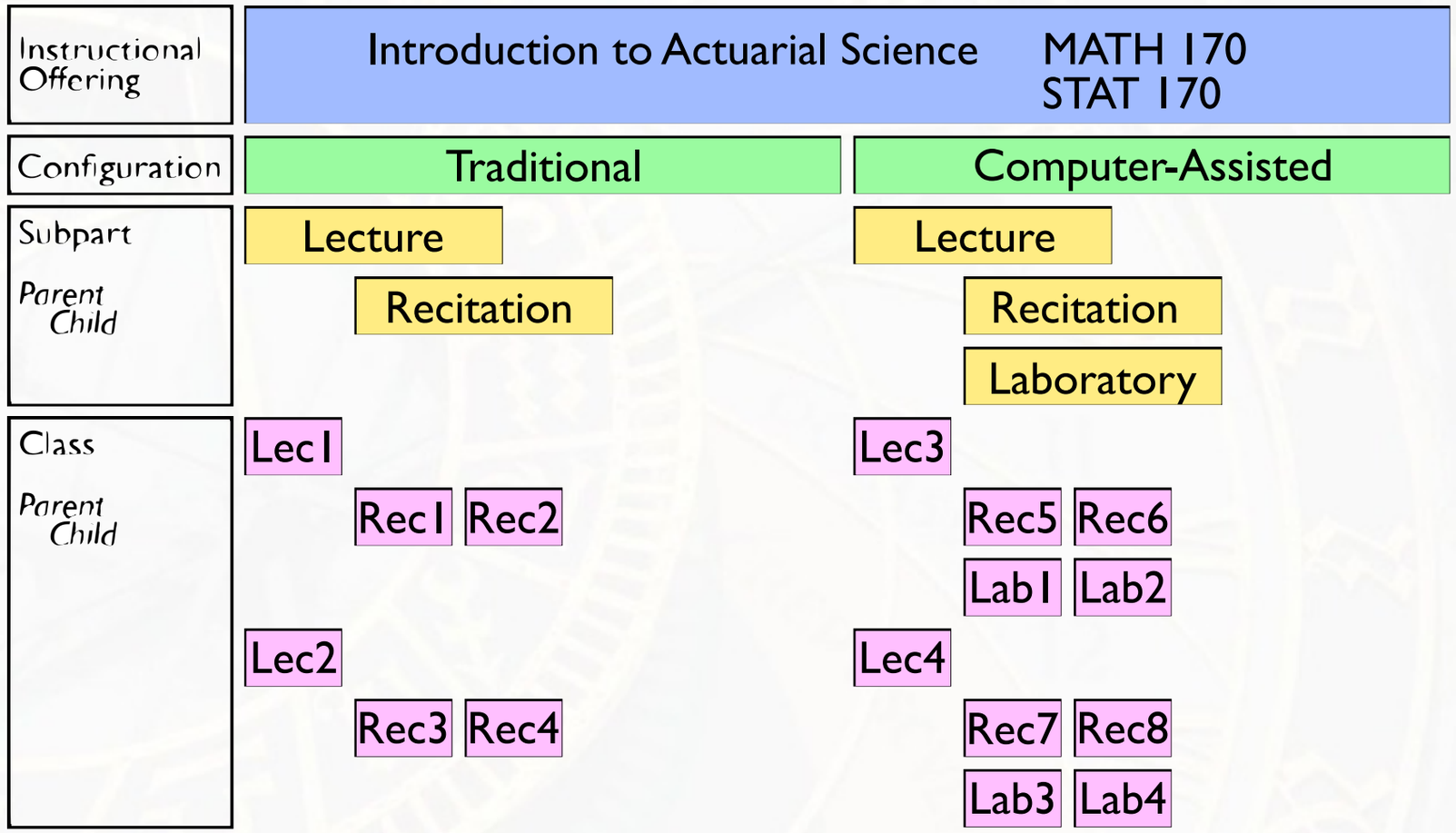
System Highlights

- Modular
  - Demand and curriculum-based course timetabling, examination timetabling, event management, student sectioning (in development)...
- Distributed
  - Allows decomposition of timetabling problems when desired (e.g., centrally managed, departmental, and other special problems)
  - Provides for coordination of multiple sub-problems and addresses competitive behavior among users
- University-wide Applicability
  - Tested on instances with up to 9,000 classes, 2,400 exams, and 39,000 students
  - Modes ranging from manual data entry to fully automated timetabling
  - Allows interactive changes



Versatility by Design

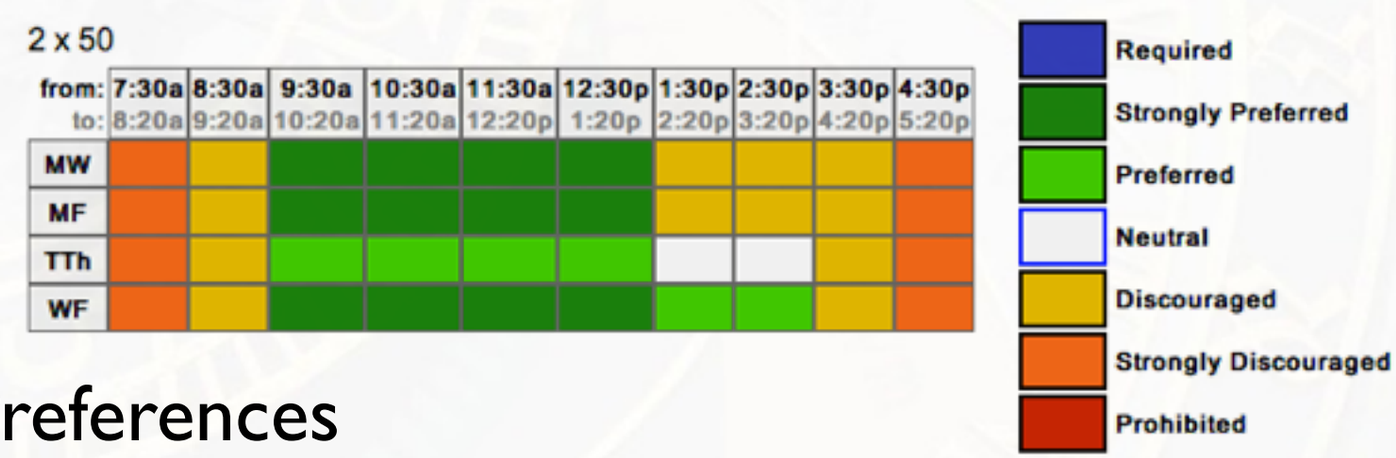
- Robust course model
  - Allows representation of even the most complex courses as individual classes plus a set of constraints
  - Constraints set on various levels of course structure
- Exceptions to rules
  - Classes can share rooms
  - Use of multiple rooms
  - Use of variable date patterns



- Solves problems with wide variety of individual characteristics
  - Local-search based constraint solver framework not tailored to specific problem attributes
  - System can support any use from completely manual to fully automated operation
- Solver framework allows problem-specific search methods
  - Consistent set of constraint-based abstractions

Input Data

- Student Requirements
  - Actual or last-like student course demand, or curricula requirements
- Time Requirements and Preferences
  - Date pattern (e.g., full term, week 5)
  - Time pattern (e.g., 3 x 50 minutes)
- Room Requirements and Preferences
  - Capacity
  - Room/building/equipment preferences
  - Building distances
  - Room availability



- Instructor Requirements and Preferences
- Distribution Requirements and Preferences
  - Constraints between several classes (e.g., precedence)
- Other (e.g., departmental balancing, efficient use of times and rooms)

Problem Model

Constraint Satisfaction and Optimization Problem

- *Variable:* class
- *Value:* assignment of both time and room(s)
- *Objective:* weighted sum of violated soft constraints

		Hard constraint	Soft constraint
Times for class	Time pattern	X	
	Individual times	X	X
Rooms for class	Individual buildings/rooms	X	X
	Individual room equipment	X	X
Resource constraints	Room	X	
	Instructor	X	
Students	Conflicts between two classes		X
Distribution constraints between classes	Time between classes	X	X
	Time precedences between classes	X	X
	Classes placed in similar times	X	X
	Same or different meeting days/times/ rooms for classes	X	X

- Some constraints may initially be hard and then weakened during search

Constraint Solver

- Local-search based framework
  - Using constraint programming primitives
  - Allows problem-specific search methods
  - Applicable to a variety of constraint satisfaction and optimization problems
- Winner of two tracks of International Timetabling Competition 2007
- Operates in multiple modes
  - Data consistency checks using hard constraints and conflict-based statistics to detect and visualize problems
  - Initial course timetabling problem
  - Minimal perturbation problem (minimize students affected by changes)
  - Interactive timetabling (support tool for user decisions)
- All modes have the same problem model
  - Use same search method (except for interactive mode)
  - But different objectives (soft constraints)

Interactive timetabling has the same objective but different search method.

Interactive Changes

Interaction

A sequence of changes based on a desired change to an individual class

- In each step, user can:
  - Commit or abandon the change
  - Select a (different) suggestion or placement
  - Remove selected assignment
  - Select another class
- Solver provides suggestions
  - Best N changes to selected classes and other affected classes
  - Resolving all hard conflicts
  - Ordered from best to least fit by the objective function

Current Assignment of MA 52700 Lec 2

Date:	Full Term
Time:	MWF 11:30a - 12:20p
Room:	EE 270
Initial Assignment:	MWF 11:30a - 12:20p EE 270
Student Conflicts:	3× BMS 82000 Lec 1 MWF 11:30a - 12:20p LYNN G167 *[hard]*
Room Locations:	23 (ARMS 1010, ARMS B061, BRNG 2280, CL50 224, ...)
Time Locations:	17 (MWF 7:30a, MWF 8:30a, MWF 9:30a, MWF 10:30a, ...)
Minimal Room Size:	118

Required | Strongly Preferred | Preferred | Neutral | Discouraged | Strongly Discouraged | Prohibited

Selected Assignments

Class	Date	Time	Room	Students
CE 37100 Lec 1	Full Term	MWF 8:30a	EE 270 → ARMS 1010	1→1 (h1→1)
MA 52700 Lec 2	Full Term	MWF 11:30a → MWF 8:30a	EE 270	3→9 (d0→9,h3→9)

Conflicting Assignments

Class	Date	Time	Room	Students	Constraint
AAE 33300 Lec 1	Full Term	MWF 8:30a → *not-assigned*	ARMS 1010 → *not-assigned*	-5 (h-3)	Room ARMS 1010

Not-assigned classes: +1 (0 → 1)

Overall solution value: +12.7 (7105 → 7117.7)

Student conflicts:
- 9× MA 52700 Lec 2 MWF 8:30a - 9:20a EE 270 / BME 69000 Lec 1 W 9:30a - 10:20a MJIS 1001 *[hard, distance]*
- 1× CE 37100 Lec 1 MWF 8:30a - 9:20a ARMS 1010 / POL 23700 Lec 1 MWF 8:30a - 9:20a ME 117 *[hard]*

Assign

Suggestions

Score	Class	Date	Time	Room	Students
+10.4	AAE 33300 Lec 1	Full Term	MWF 8:30a → MWF 3:30p	ARMS 1010 → CL50 224	+138 (c+18,d+13,h+95)
	MA 16100 Lec 1	Full Term	MWF 3:30p → MWF 7:30a	CL50 224 → EE 129	
+24.6	AAE 33300 Lec 1	Full Term	MWF 8:30a → MWF 7:30a	ARMS 1010 → EE 129	+1 (d+9,h+3)
+25.3	AAE 33300 Lec 1	Full Term	MWF 8:30a → MWF 7:30a	ARMS 1010 → MATH 175	+1 (d+9,h+3)
+27.6	AAE 33300 Lec 1	Full Term	MWF 8:30a → MWF 7:30a	ARMS 1010 → WTHR 200	+11 (d+19,h+3)
	OLS 27400 Lec 1	Full Term	MW 7:30a	WTHR 200 → EE 129	

Interactive Solver

Branch & Bound with a very limited depth (and time frame)

- Typically not more than two additional changes are allowed
- User can increase depth and/or time limit and guide the search by filtering the results

Problem	pu-fal07-llr		pu-spr07-llr	
Classes	891		803	
Classes fixed in time and room [%]	31.0		33.8	
Time limit [s]	-	5	-	5
No suggestions found [%]	1.6	2.3	0.8	0.8
Optimal suggestions found [%]	98.4	51.5	99.2	67.0
Complete space explored [%]	98.4	21.5	99.2	33.3
Number of suggestions	232.8	174.9	228.6	184.5
Number of backtracks	66367.9	2886.9	13949.1	2592.0
Time spent [s]	128.6	4.7	39.9	4.2
Improvements in objective function [%]	+1.1	+0.8	+0.9	+0.7

Results comparing suggestions with and without 5 second time limit for the interactive solver with 2 additional changes

Selected Publications

Complex university course timetabling
H. Rudová, *T. Müller*, *K. Murray*, Journal of Scheduling, DOI 10.1007/s10951-010-0171-3, To Appear, 2010.

Comprehensive approach to student sectioning
T. Müller, *K. Murray*, Annals of Operations Research, DOI 10.1007/s10479-010-0735-9, To Appear, 2010.

ITC2007 solver description: a hybrid approach
T. Müller, Annals of Operations Research, Volume 127, Number 1 (November 2009), Pages 429-446, ISSN 0254-5330 (Print) 1572-9338 (Online), DOI 10.1007/s10479-009-0644-y, 2009.

Modeling and Solution of a Complex University Course Timetabling Problem
K. Murray, *T. Müller*, *H. Rudová*, In Edmund Burke and Hana Rudova, editors, Practice and Theory of Automated Timetabling, Selected Revised Papers, Springer-Verlag LNCS 3867, Pages 189-209, 2007.

Minimal Perturbation Problem in Course Timetabling
T. Müller, *R. Barták*, *H. Rudová*, In Edmund Burke and Michael Trick, editors, Practice and Theory of Automated Timetabling, Selected Revised Papers, Pages 126-146. Springer-Verlag LNCS 3616, 2005.

Minimal Perturbation Problem - A Formal View
R. Barták, *T. Müller*, *H. Rudová*, Neural Network World (2003), Volume 13, Number 5, Pages 501-511.

University Course Timetabling with Soft Constraints
H. Rudová, *K. Murray*, Practice And Theory of Automated Timetabling, Selected Revised Papers. Springer-Verlag LNCS 2740, Pages 310-328, 2003.

Demonstration

http://demo.unitime.org