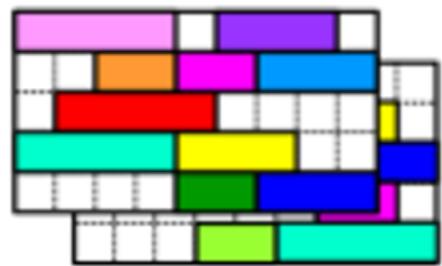


# Open Apereo 2015

Higher Education ... Open Source in a New Age



UNI TIME

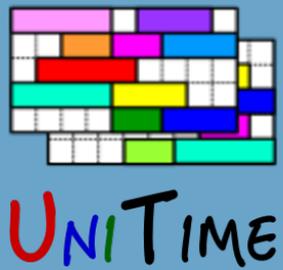
## Examination Timetabling in UniTime

*(including state of the project)*

June 2015

Tomáš Müller

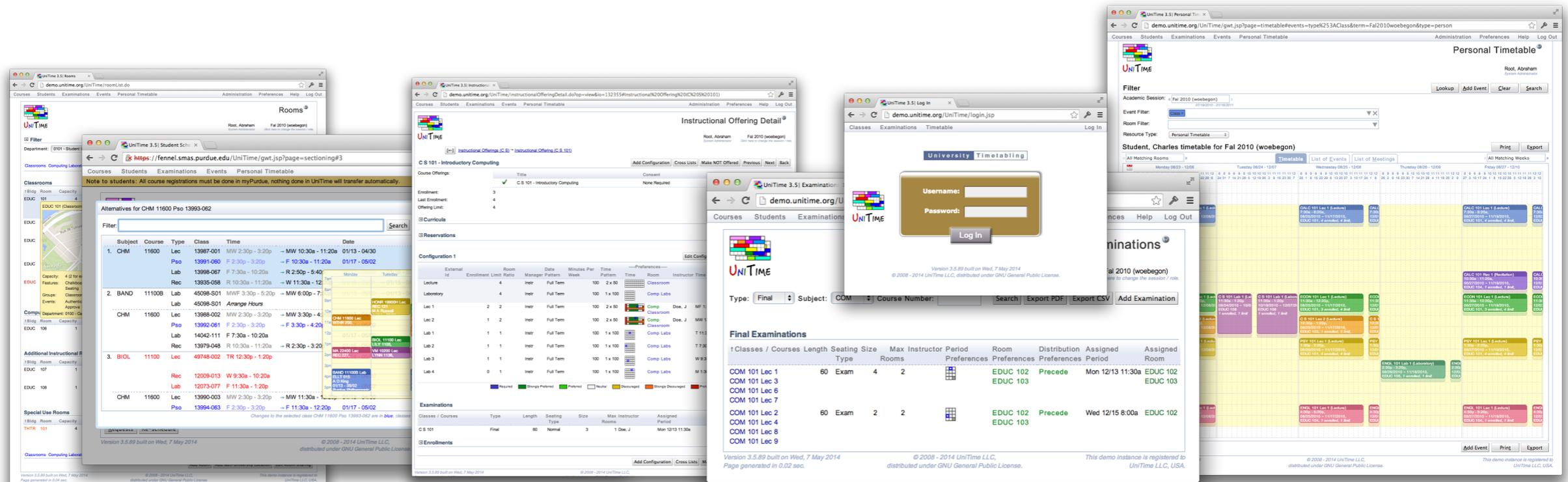


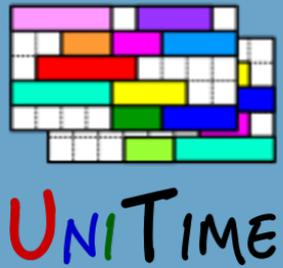


# Introduction

## What is UniTime?

- Comprehensive academic scheduling solution
- Four components: course timetabling, examination timetabling, student scheduling and event management
- Open source, web-based, written in Java using modern technologies
- Using state-of-the-art optimization algorithms
- Distributed data entry and timetabling in multi-user environments



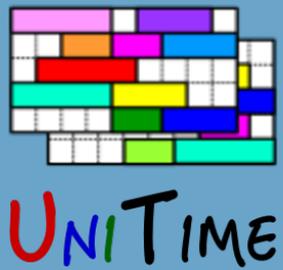


# State of the Project

## Achievements

- Graduated from the Apereo incubation (March 2015)
  - Formed PMC ([pmc@unitime.org](mailto:pmc@unitime.org))
  - Project Governance Rules
  - New licensing model (Apache License, Version 2)
  - Code base moved to GitHub ([github.com/UniTime](https://github.com/UniTime))
- Online student scheduling at Purdue (Banner XE API)
- Reached 500k of lines of code (including the CPSolver)
- About 6,000 visits of [unitime.org](http://unitime.org) and about 1,000 monthly downloads
- Steady increase in interest and adoption from literally around the world
  - USA, Czech Republic, Pakistan, Croatia, Poland, Turkey, Peru, Kuwait,...
- ... but still very little outside contributions

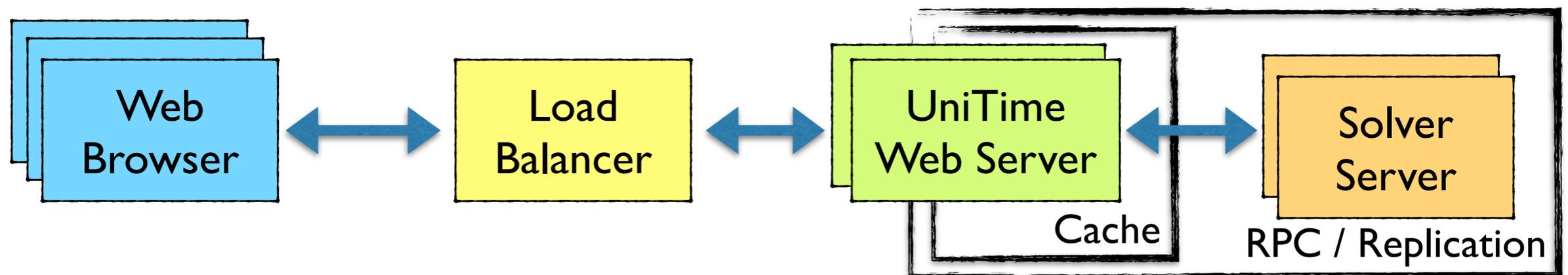




# State of the Project

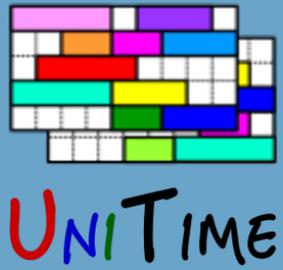
## UniTime 3.5 / 4.0 (current version)

- Released in December 2014 / March 2015
- Same features, UniTime 4.0 has a new license (Apache vs. GNU GPL)
- Clustering (Hibernate L2 cache, solver RPCs, online scheduling data)
- Online Student Scheduling (replication, SIS integration, expectations, reports)
- Multi-core solver capability (CPSolver 1.3, new algorithms and constraints)
- Mobile (MGWT introduced)
- Many additional improvements across all the components



See <http://builds.unitime.org/UniTime4.0/Release-Notes.xml> for more details.





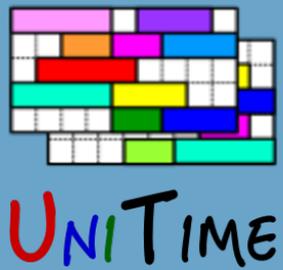
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## UniTime 4.1 (in development)

- Planned release late 2015 / early 2016
- New class duration model (can consider date pattern and holidays)
- Cancelled classes
- New rooms pages (ability to enter data across terms, floor plans, etc.)
- More interfaces (especially with Ellucian Banner and Degree Works)
- Interactive and MPP mode of the student scheduling solver
- Ability to automatically keep students of the same group together
- Many additional improvements across all the components

See [t.co/Fq7ePP9mXa](https://t.co/Fq7ePP9mXa) for more details.





# State of the Project

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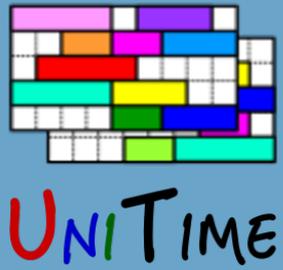
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## Long Term

- Constraint Solver: instructor and student group scheduling
- UI: moving from Struts to GWT, localization, documentation, mobile
- Interfaces: IMS Course Planning & Scheduling, Spring Integration

See [t.co/Fq7ePP9mXa](https://t.co/Fq7ePP9mXa) for more details.



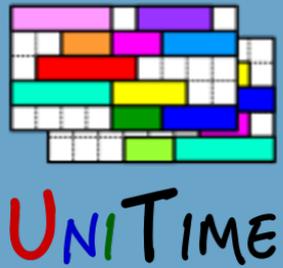


# Examination Timetabling

## What is Examination Timetabling?

- The process of assigning examinations to time periods and locations
- A difficult optimization problem with many competing objectives
  - Student conflicts, faculty requirements, space constraints





# Examination Timetabling

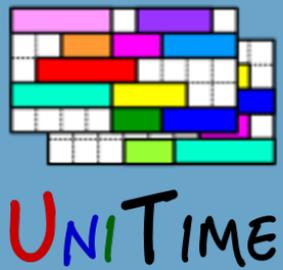
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- Make process easier to manage, fairness and satisfaction, what-ifs





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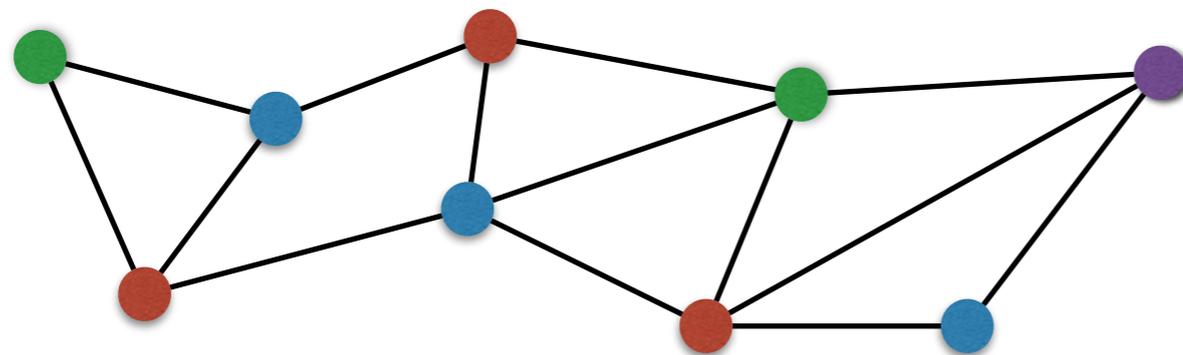
## Many flavors

- Final examinations, evening examinations, mid-terms, ...
- Additional objectives

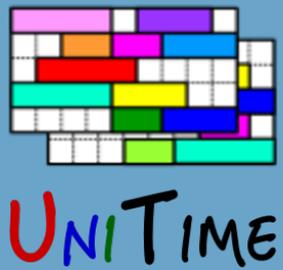


## Well known research problem

- Examination problem has been studied extensively
- NP complete (period assignment  $\sim$  graph coloring)
- Carter's data sets from 1996 (13 "real-world" problems including Purdue)



Vertex: examination  
 Edge: students in common  
 Color: examination period



# Examination Timetabling

## Well known research problem

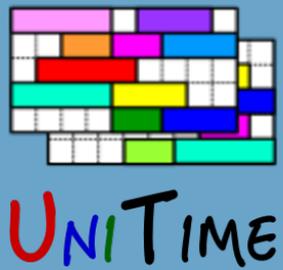
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## At Purdue

- Large problem (~1,900 exams with 120,000 enrollments and 29 periods)
- Solved by UniTime since 2008
- Using a local-search based hybrid approach, winner of the ITC 2007\*
- Nine large instances from Purdue University made publicly available

\*) More details are in the paper T. Müller, ITC2007 solver description: a hybrid approach, Annals of Operations Research, November 2009, DOI 10.1007/s10479-009-0644-y





# Examination Data

## Input Data

- Examinations (*with students enrolled in them*)
- Periods (*not overlapping, can have various durations*)
- Rooms (*with capacities, availabilities, and period preferences*)
- Individual examination requirements and preferences
- Distribution constraints (*same/different room, same/different period, precedence*)

	from: 8:00a	10:30a	1:00p	3:30p	7:00p
	to: 10:00a	12:30p	3:00p	5:30p	9:00p
Mon 12/09					
Tue 12/10					
Wed 12/11					
Thu 12/12					
Fri 12/13					
Sat 12/14					

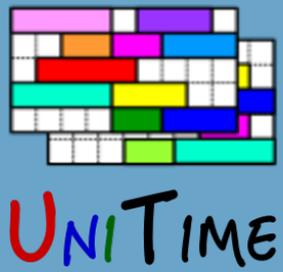
	Required
	Strongly Preferred
	Preferred
	Neutral
	Discouraged
	Strongly Discouraged
	Prohibited

## Evening Examinations

- Mondays - Thursdays
- 6:30p - 7:30p or 8p - 10p
- 3 days & early / late
- 2-3 exams for a course
- Student availability

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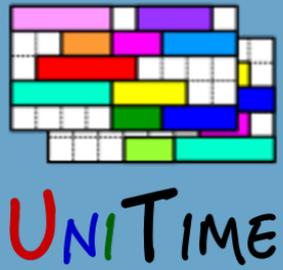
# Example Data Entry

## Final Examinations

↑ Classes / Courses	Length	Seating Type	Size	Max Rooms	Instructor	Period Preferences	Room Preferences	Distribution Preferences	Assigned Period	Assigned Room
MGMT 20000	120	Exam	881	4					Thu 12/12 7:00p	LAMB F101
MGMT 20010 50874-T01	120	Exam	205	4			PHYS 114 PHYS		Mon 12/09 8:00a	WTHR 200
MGMT 20100	120	Exam	437	4					Thu 12/12 3:30p	STEW 183
MGMT 29000B 23766-002	120	Exam	36	4			KRAN		Fri 12/13 10:30a	KRAN G016
MGMT 30400	120	Exam	115	4					Tue 12/10 1:00p	LILY 1105
MGMT 30500 23769-001	120	Exam	280	4			RAWL 1086	Same Per	Wed 12/11 1:00p	WTHR 200
MGMT 30500 23771-003							RAWL			WTHR 104
MGMT 30500 23772-004										
MGMT 30500 23770-002										
MGMT 30500 23773-005	120	Exam	70	4			RAWL 1062	Same Per	Wed 12/11 1:00p	WTHR 172
MGMT 30600	120	Exam	236	4					Mon 12/09 8:00a	STEW 183

Required
  Strongly Preferred
  Preferred
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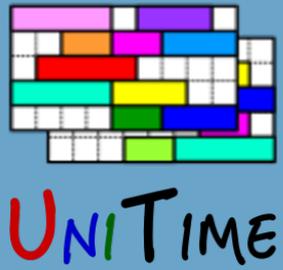


# Examination Problem

## Hard Constraints

- No two exams in the same period and room
- Examination must fit the period and room (or rooms)
- Room must be available
- An exam cannot be placed in a period or a room that is prohibited
- Required (*hard*) distribution constraints must be satisfied





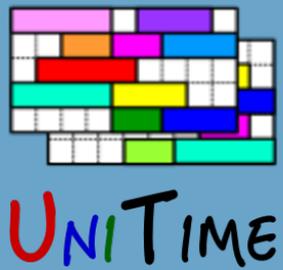
# Examination Problem

## Soft Constraints / Objectives

- Direct conflicts
  - More than two exams on a day
  - Back-to-backs
  - Period, room, and distribution penalties
- ... and a few others
- Minimize room splits (*and the distance between these rooms, if an exam is split*)
  - Distance to original room (*i.e., the room where the class took place*)
  - Large exams first
  - Rotation (*average period*)

} student conflicts





# Example Data

## Purdue Fall 2012 Final Examinations

- 29 periods, 1 864 exams, 33 279 students, 117 271 enrollments, 347 rooms
- Hard in size, density and utilization of large rooms

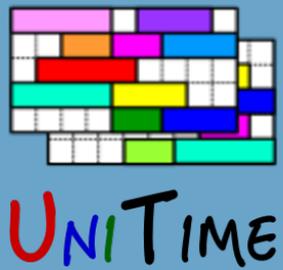
<i>Fall 2012</i>	All	$\geq 100$ seats	$\geq 200$ seats	$\geq 400$ seats	$\geq 600$ seats
Rooms	347	30 (16)	12 (8)	7 (3)	2 (2)
Exams	1,864 (819)	248 (179)	87 (69)	37 (32)	22 (21)
Density	3.3%	29.6%	60%	81.2%	83.6%

*(examination seating in brackets)*

- Chromatic number of at least 27

**Density:** probability that two exams have at least one student in common





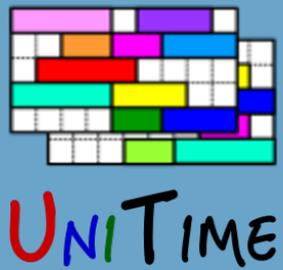
# Example Results

Fall 2012	Production	Base	Color	Split
Direct Conflicts	79.7 ± 3.4	32.7 ± 3.9	0.0 ± 0.0	0.0 ± 0.0
More Than 2 A Day	345.2 ± 10.0	344.8 ± 26.6	650.7 ± 38.0	71.3 ± 11.6
Back-To-Back	4107.2 ± 74.5	4792.1 ± 151.2	6342.0 ± 133.5	1802.7 ± 112.0
Period Preferences [%]	91.5 ± 0.3	88.2 ± 0.4	85.8 ± 0.3	88.6 ± 0.4
Room Preferences [%]	74.3 ± 0.5	72.4 ± 0.3	72.5 ± 0.4	72.3 ± 0.7
Room Splits	43.0 ± 2.3	48.5 ± 8.9	19.8 ± 9.7	46.8 ± 3.6
Unavailable Period	-	-	12.7 ± 1.3	-
Unavailable Room	-	-	10.8 ± 0.9	-
Violated Distribution	-	-	2.8 ± 0.8	-
Period Splits	-	-	-	64.10 ± 3.54

*Average of 10 runs, 2 hour time limit*

More details are in the paper T. Müller, Real-life Examination Timetabling, Journal of Scheduling, August 2014, DOI 10.1007/s10951-014-0391-z





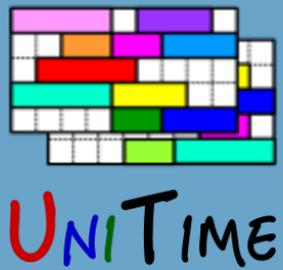
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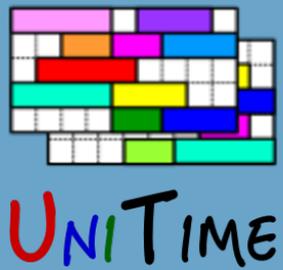
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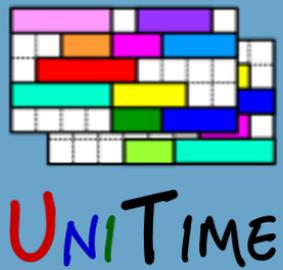
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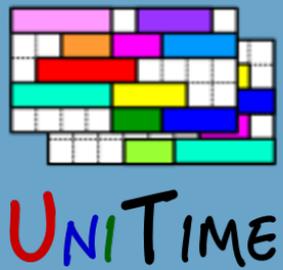
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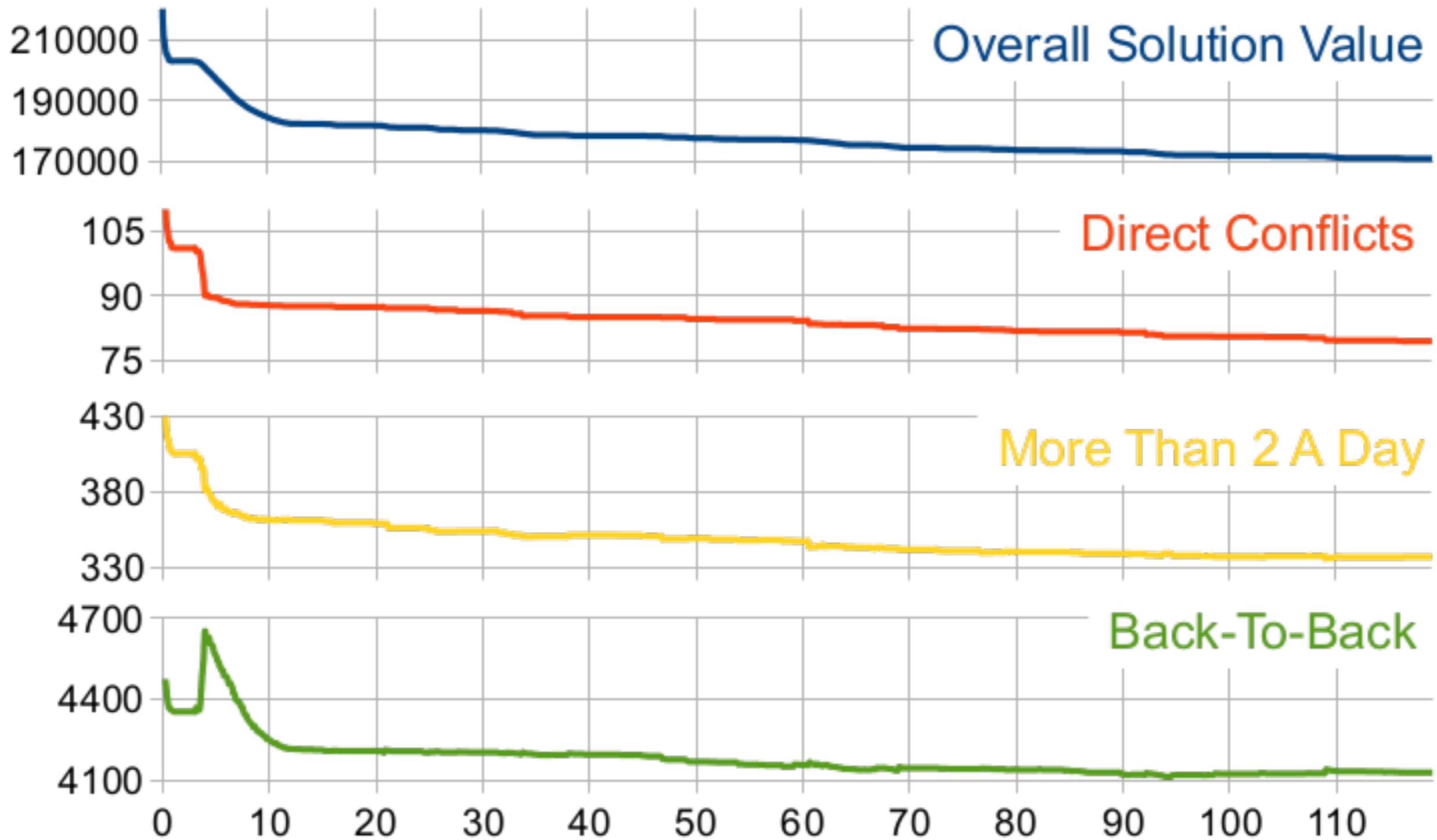
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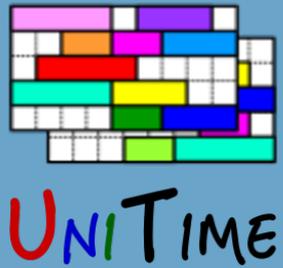
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# Example Results





# Conclusion

## Examination Timetabling in UniTime

- Can be used for large problems
- Is very general and can be used on many higher education institutions
- Is easy to extend and/or customize

## For more details, please see us at the conference

- Course Timetabling in UniTime (Sunday, 1 pm - 4 pm)
- Meeting State Mandated Guidelines for Student Degree Progress at Purdue (Monday, 10:15am in Maryland A)
- Case Study: Course Timetabling with UniTime at Masaryk University (Monday, 2:30pm in Maryland F)
- Showcase: UniTime (Monday, 5:30 pm - 7 pm)
- Or visit [www.unitime.org](http://www.unitime.org)

An online demo is available at <https://demo.unitime.org>

