Real-life Curriculum-based Timetabling

PATAT 2012

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Agenda

- Curriculum model
  - Electives and optional courses
  - Courses with multiple alternative sections
- Curriculum to enrollment transformation
  - Motivation
  - Modeling
  - Algorithm
- Experiments
  - Real application at Faculty of Education, Masaryk University
  - Transformation
  - Timetabling
- Conclusion
  - Possible extensions to the proposed model

Curriculum Model

- Typical Curriculum Model
  - List of curricula, each curriculum has a list of classes
  - Classes of the same curriculum cannot overlap in time
  - And the usual... *(classes, instructors, rooms, other constraints)*
- Common Issues
  - Elective and optional courses
  - Alternatives in the course structure
  - Courses can be shared between multiple curricula

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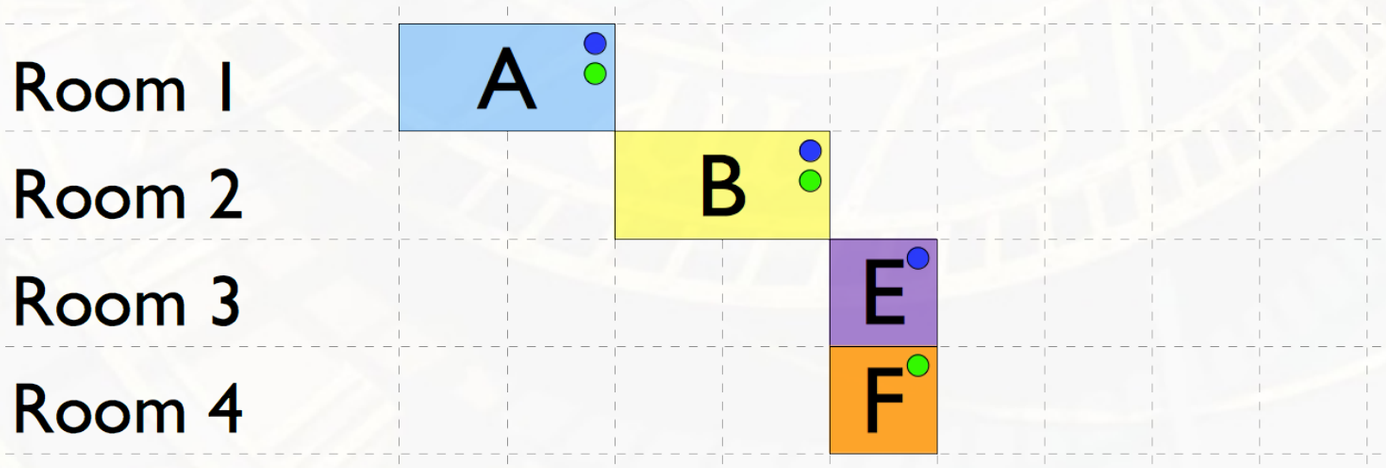
Electives: students only need to take one of the given N courses

Conflicts between optional courses could be minimized (instead of prohibited)



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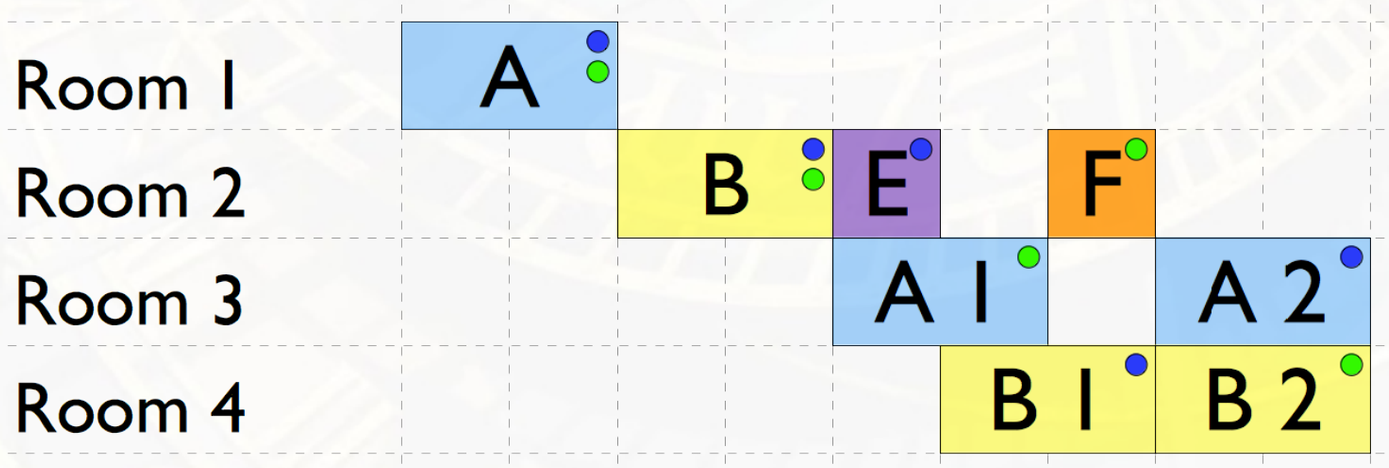
A course may have a lecture and multiple seminars



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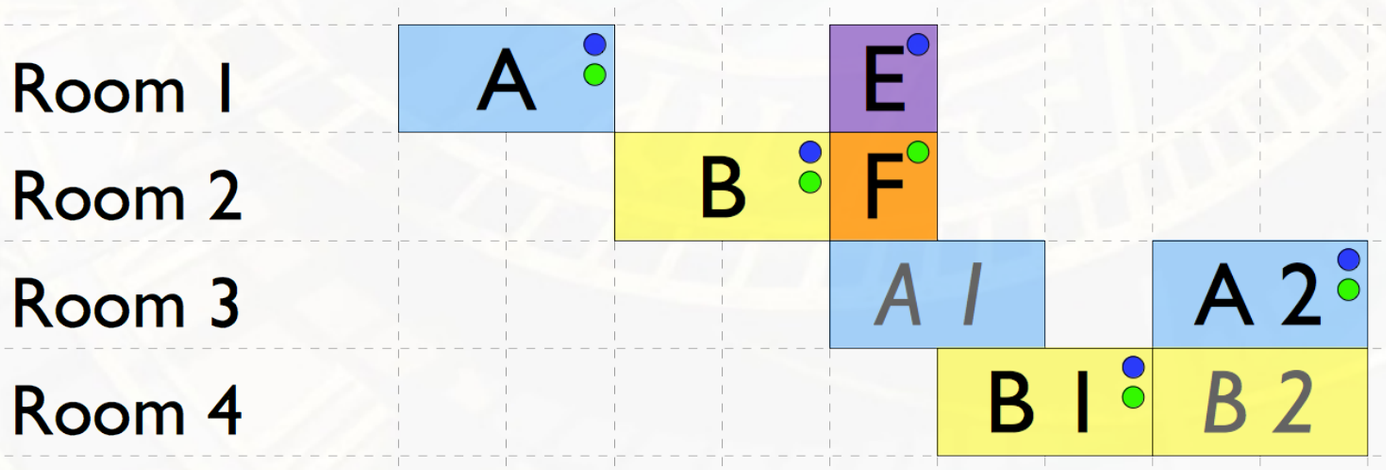

Proposed Curriculum Model

- For each curriculum
  - There is a number of students,

    and a list of courses with their course projections

    course projection: number of students that are expected to attend the course
  - Courses can be grouped together

Conflicting group: same students

Non conflicting group: different students

Course Projections

Group	Course	01
Required	ALG 101	100.0%
Required	CALC 101	100.0%
Elective	ENGL 101	60.0%
Elective	SPAN 101	40.0%
	BIOL 101	10.0%
	CHM 101	20.0%

Course Projections

Group	Course	01
M1 and M2 M or N or O	M1	50.0%
M1 and M2	M2	50.0%
N1 and N2 M or N or O	N1	30.0%
N1 and N2	N2	30.0%
O1 and O2 M or N or O	O1	20.0%
O1 and O2	O2	20.0%

Proposed Curriculum Model

- Target Share
  - For each pair of courses of a curriculum
  - Percentage of students that are expected to attend both courses

$$t_{c,d} = \begin{cases} 1 & \text{if courses } c, d \text{ are in a conflicting group} \\ 0 & \text{if courses } c, d \text{ are in a non conflicting group} \\ e_c\, e_d & \text{otherwise (} e_c \text{ is a course projection of } c \text{)} \end{cases}$$

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N1 and N2		N2	30.0%
O1 and O2	M or N or O	O1	20.0%
O1 and O2		O2	20.0%

Solution Approach

- UniTime
  - Comprehensive course timetabling system
  - Post-enrollment based
  - Can deal with alternatives in the course structure

Courses

ALG 101
COM 101
PSY 101
ECON 101
GER 101

Student requests courses

UniTime

Classes

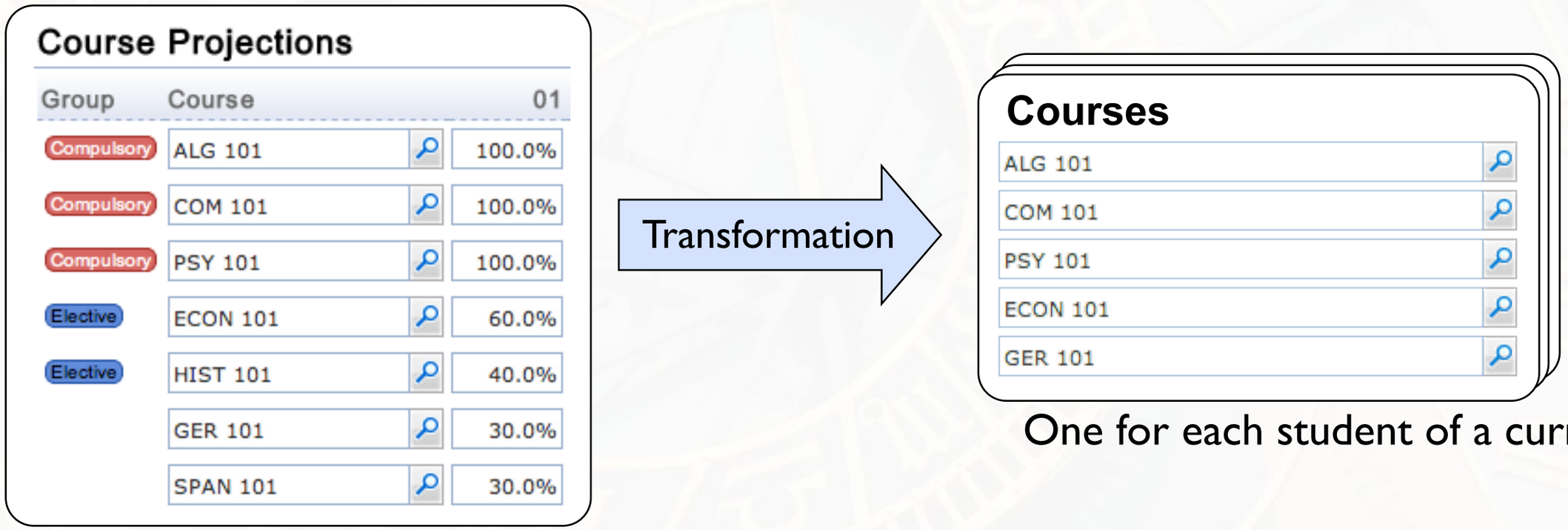
Subject	Course	Type	CRN	Days	Start	End	Date	Room	Instructor
ALG	101	Lec	1	MWF	9:30a	10:20a	08/23 - 12/10	EDUC 103	J. Doe
COM	101	Lec	2	TR	4:30p	5:45p	08/24 - 12/09	EDUC 102	
PSY	101	Lec	1	MWF	1:30p	2:20p	08/23 - 12/10	EDUC 101	
ECON	101	Lec	1	MWF	11:30a	12:20p	08/23 - 12/10	EDUC 101	
GER	101	Lec	2	MWF	12:30p	1:20p	08/23 - 12/10	EDUC 102	
		Lab	3	T	10:30a	11:20a	08/24 - 12/07	EDUC 108	

UniTime assigns classes

- Extending UniTime
  1. Defining curriculum model
  2. Transformation of curriculum model to post-enrollment
  3. Applying UniTime with post-enrollment model

Solution Approach

- Transformation of curriculum model to post-enrollment
  - Student course requests are generated for each curriculum
  - Respecting course projections and target shares



One for each student of a curriculum

- Reason for the transformation
  - There is no direct mapping between curricula and classes
  - Some curriculum to class assignment must be made
    - *Curriculum ~ list of (pairs of) classes that cannot overlap in time*
  - A curriculum may get split based on the electives, optionals, and class sizes

Curriculum To Enrollment

- Input (for each curriculum)
  - Number of students in the curriculum x and the course projections e_c
  - Target share between pairs of courses $t_{c,d}$
- Output
  - Student course requests for the given number of students x
- Objectives
  - Assign students to courses so that each course has the desired number of students xe_c
  - Minimize the total difference between
    - target share $t_{c,d}\,x$
    - and the actual share $s_{c,d}$
    - between any pair of courses c, d

$$F(\theta) = \sum_{c,d \in \mathrm{C},\, c \neq d} |t_{c,d}\, x - s_{c,d}|$$

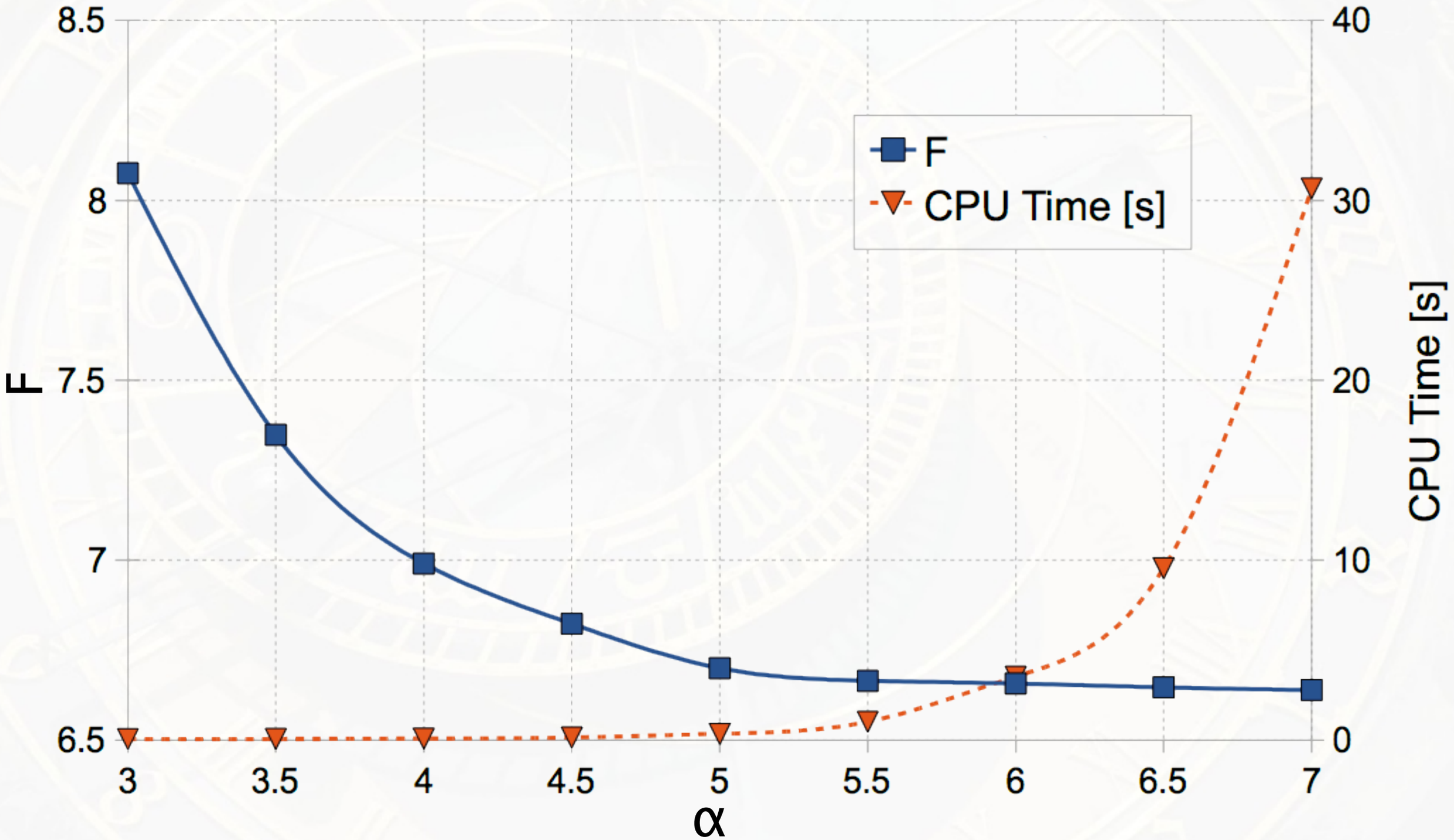
Curriculum To Enrollment

- Construction Phase
  - Iterative, while there is a course with less students than expected
    1. Pick a course with the highest number of unassigned requests
    2. Pick a student with the smallest impact on the objective function
    3. Assign student to the course

Student swap:
One student is unassigned from the course, one student is assigned to the course.

- Great Deluge Phase
  - Initial bound $B = 1.25 \times F$
  - Iterative, while lower bound $0.75 \times F$ or $F = 0$ is not reached
    1. Pick a course randomly
    2. Choose a random student swap
    3. Accept if improving or if F does not exceeds the bound
    4. Decrease the bound $F = 10^{-\alpha} \times F$

Curriculum To Enrollment



Bound is decreased by $10^{-\alpha}$ in each step

Application at Masaryk University

Fall 2011 Spring 2012	All together	Present (P)	Combined (K)	Lifelong (C)
Curricula	574	470	56	56
	543	442	53	48
Students	7,569	4,301	2,562	706
	6,803	3,852	2,362	589
Students	13.19	9.15	45.75	14.71
per classif.	12.53	8.71	44.57	12.27
Courses	30.61	34.63	18.32	5.67
per classif.	27.44	31.06	15.62	7.21
F	7.05 ± 0.01	8.24 ± 0.01	3.14 ± 0.03	0.00 ± 0.00
	6.66 ± 0.01	8.04 ± 0.01	1.02 ± 0.03	0.13 ± 0.00
F after 1. phase	11.97 ± 0.13	13.25 ± 0.13	11.53 ± 0.14	0.04 ± 0.06
	10.87 ± 0.11	11.99 ± 0.12	11.03 ± 0.12	0.31 ± 0.06
CPU time [s]	3.36 ± 0.06	3.08 ± 0.05	8.58 ± 0.12	0.01 ± 0.00
	3.53 ± 0.07	2.88 ± 0.06	12.14 ± 0.16	0.02 ± 0.03

Application at Masaryk University

	Fall 2011 automated	Fall 2011 published	Spring 2012 automated	Spring 2012 published
Courses (comp. & elect.)	1,225 (1,156)		900 (870)	
Classes (comp. & elect.)	1,831 (1,575)		1,665 (1,408)	
Enrollments (comp. & elect.)	57,861 (52,396)		45,786 (45,400)	
Student conflicts	418 (0.63 %)	456 (0.69 %)	477 (1.02 %)	417 (0.89 %)
among comp. & elect.	112 (0.17 %)	140 (0.21 %)	96 (0.20 %)	93 (0.20 %)
Time preferences	89.27 %	89.93 %	94.88 %	95.32 %
Room preferences	78.03 %	79.92 %	85.15 %	86.50 %
Distribution preferences	84.50 %	80.41 %	90.49 %	90.49 %
Interactive changes		355		275
of time		183		105
of room		300		218

Input data

Base optimization criteria

Modifications

Conclusion

- New approach to curriculum timetabling
  - Offers a general way how a curriculum timetabling can be solved using a post-enrollment solver
- Future work
  - Students that require multiple curricula
    - Example: multiple specializations, or a common part + specialization
    - Natural extension of the presented model
  - Combining historic data to estimate target shares
  - Further study in comparing this approach with the traditional one
- For more details
  - See our paper
  - Visit http://www.unitime.org