



Interactive Timetabling:

Concepts, Techniques, and Practical Results

PATAT '02

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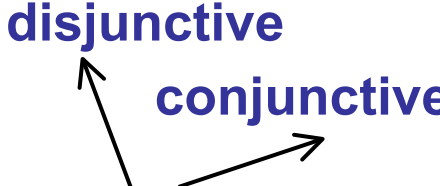


Introduction - Timetabling

- Allocation of activities
- Resources
- Various constraints
- Interactivity
 - combination of automated timetabling with user interaction
 - solution is built step by step
 - presentation of sub-results during execution



The Model

- Time Slots
 - Time Preferences
 - soft and hard constraints
 - Activities *~ Lectures, Seminars*
 - name, duration, time preferences
 - sets of needed resources - resource groups
 - Resources *~ Rooms, Classes, Classrooms, ...*
 - name, time preferences
 - Dependencies
 - binary, between two activities
 - before, closely before, concurrently
- disjunctive
conjunctive
- 



The (Partial) Solution

- Every (scheduled) activity has all required resources reserved.
 - all from conjunctive, one from disjunctive group
- Two (scheduled) activities cannot use the same resource at the same time.
- No hard constraint of time preference is violated.
- All dependencies are satisfied.

Furthermore:

We want to minimize the number of violated soft constraints.

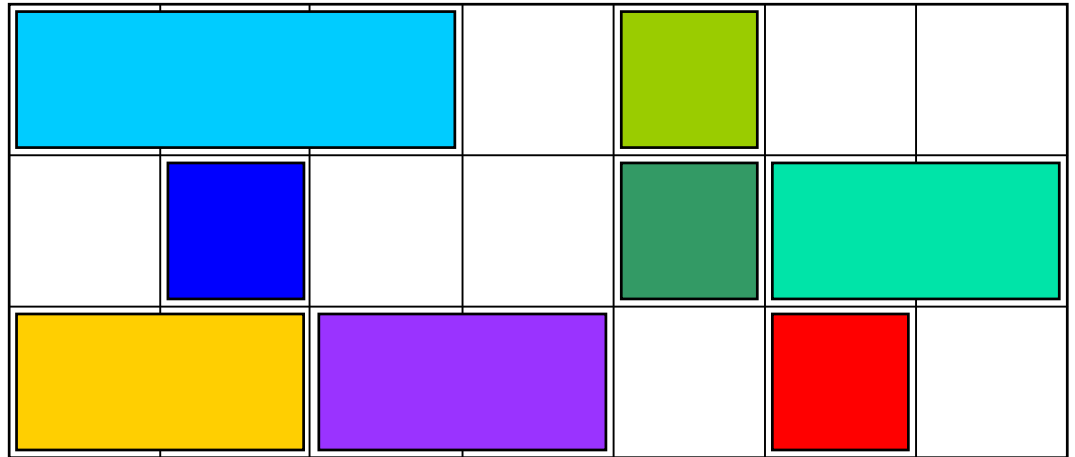


The Interactive Solver

- Basic Approaches
 - local search
 - backtracking based search
- Interactive Solving Algorithm
 - forward based search
 - works in iterations
 - extending feasible partial solution
 - interactivity



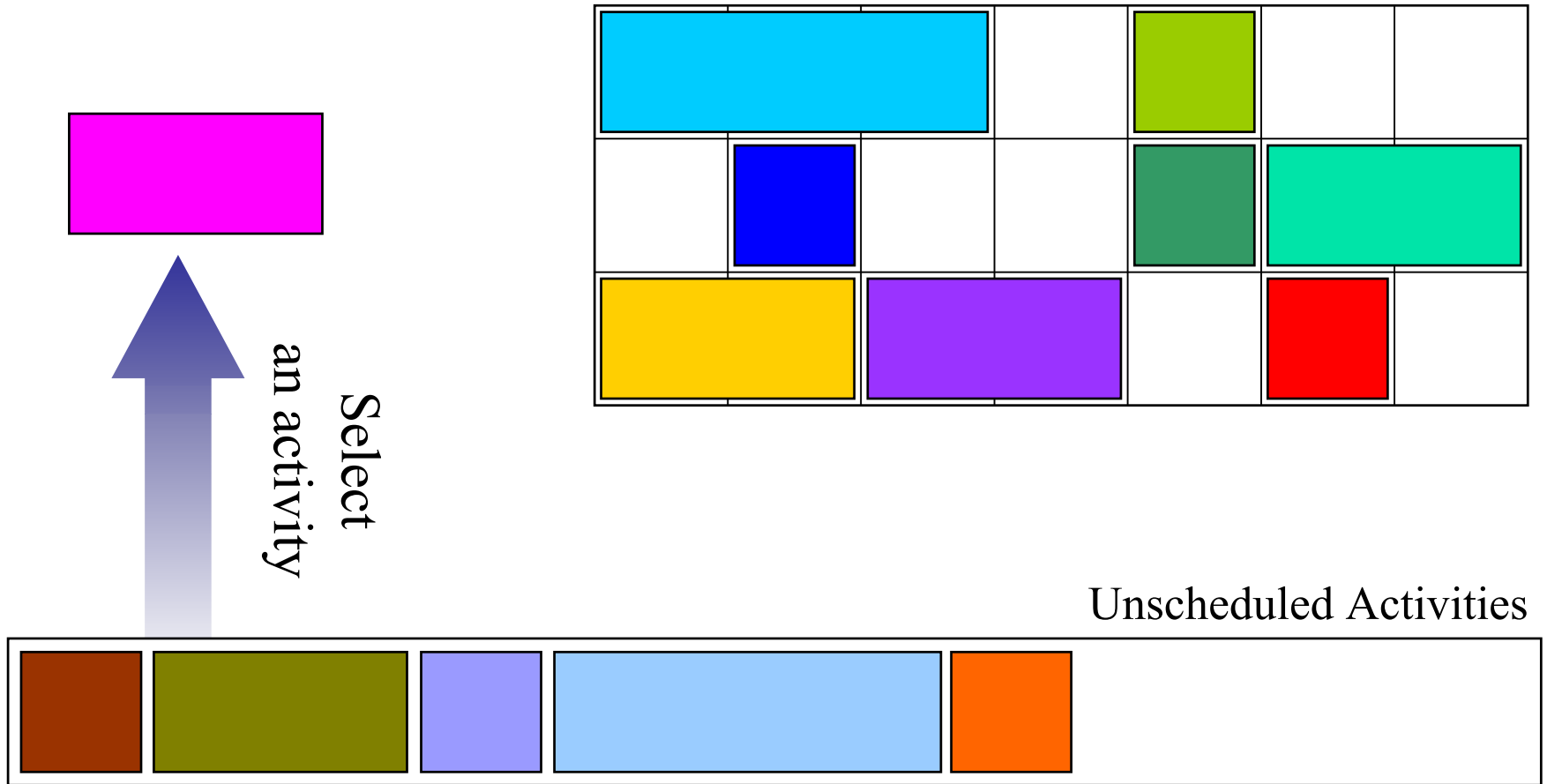
The Interactive Solver



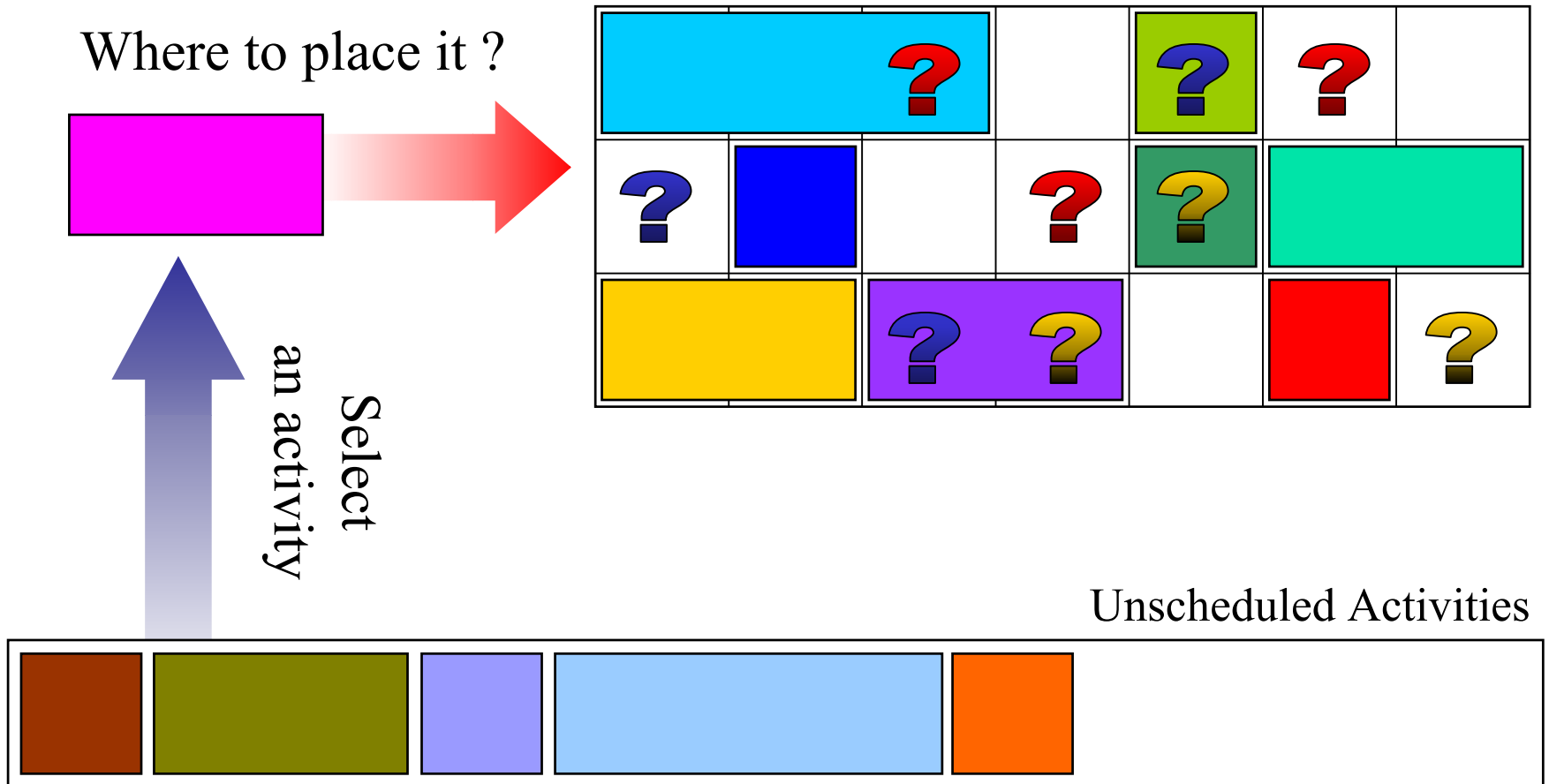
Unscheduled Activities



The Interactive Solver

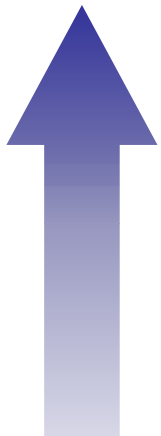


The Interactive Solver

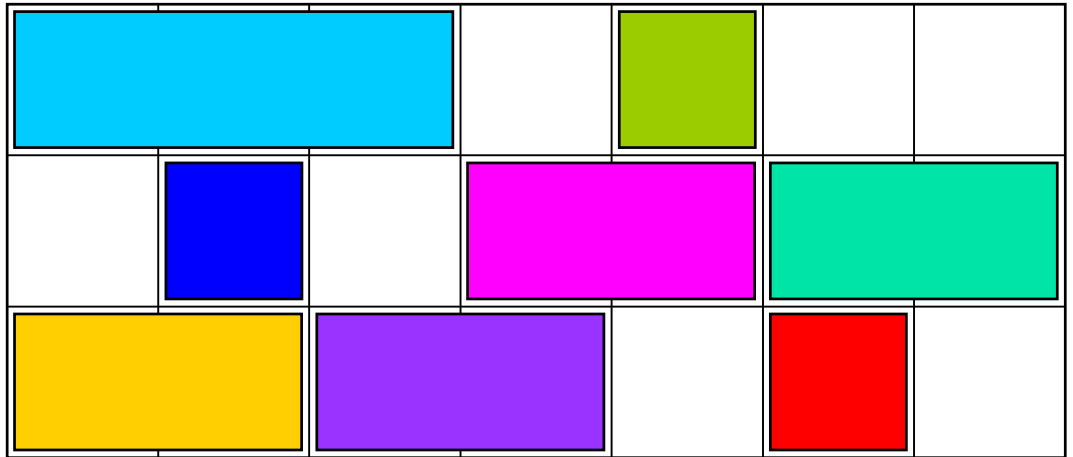


The Interactive Solver

Where to place it ?



Select
an activity



Some activities
can be removed



Unscheduled Activities





Activity Selection

- First-fail Principle
- Weighted Sum
 - for each unscheduled activity
 - several criteria
 - in how many dependencies does the activity participate
 - in how many locations can the activity be placed
 - ...
 - an activity with minimal value selected

Improvement:

Select randomly 20% of unscheduled activities first.



Location Selection

- Select The Best-fit Place
- Weighted Sum
 - for each possible location
 - several criteria
 - a number of violated soft constraints
 - a number of conflict activities
 - ...
 - a location with minimal value is selected

Improvement:

Random selection of the top N places.



Practical Results: Faculty of Mathematics and Physics

- Model Extension
 - alternative activities
 - at least one possibility
 - maximize possibilities for each assigned resource (class)
 - three different buildings
 - one free slot for crossing
 - minimize the number of crossings
 - time preferences
 - class: max 10 hours a day, 6 hours without a break
 - teacher: max 8 hours a day, 6 hours without a break
 - minimize the number of free hours during the day

Leads to:

Extension of activity & location selection criteria.



Practical Results: Faculty of Mathematics and Physics

- Problem size:
 - 5 days a week, 15 time slots (hours) a day
 - one time slot \sim 45 minutes
 - 746 lectures (1512 time slots)
 - 349 classes and sub-classes
 - 479 teachers
 - 30 classrooms
 - 3 different locations (buildings)
- Solution:
 - approx. 8-10 minutes
 - no user intervention needed



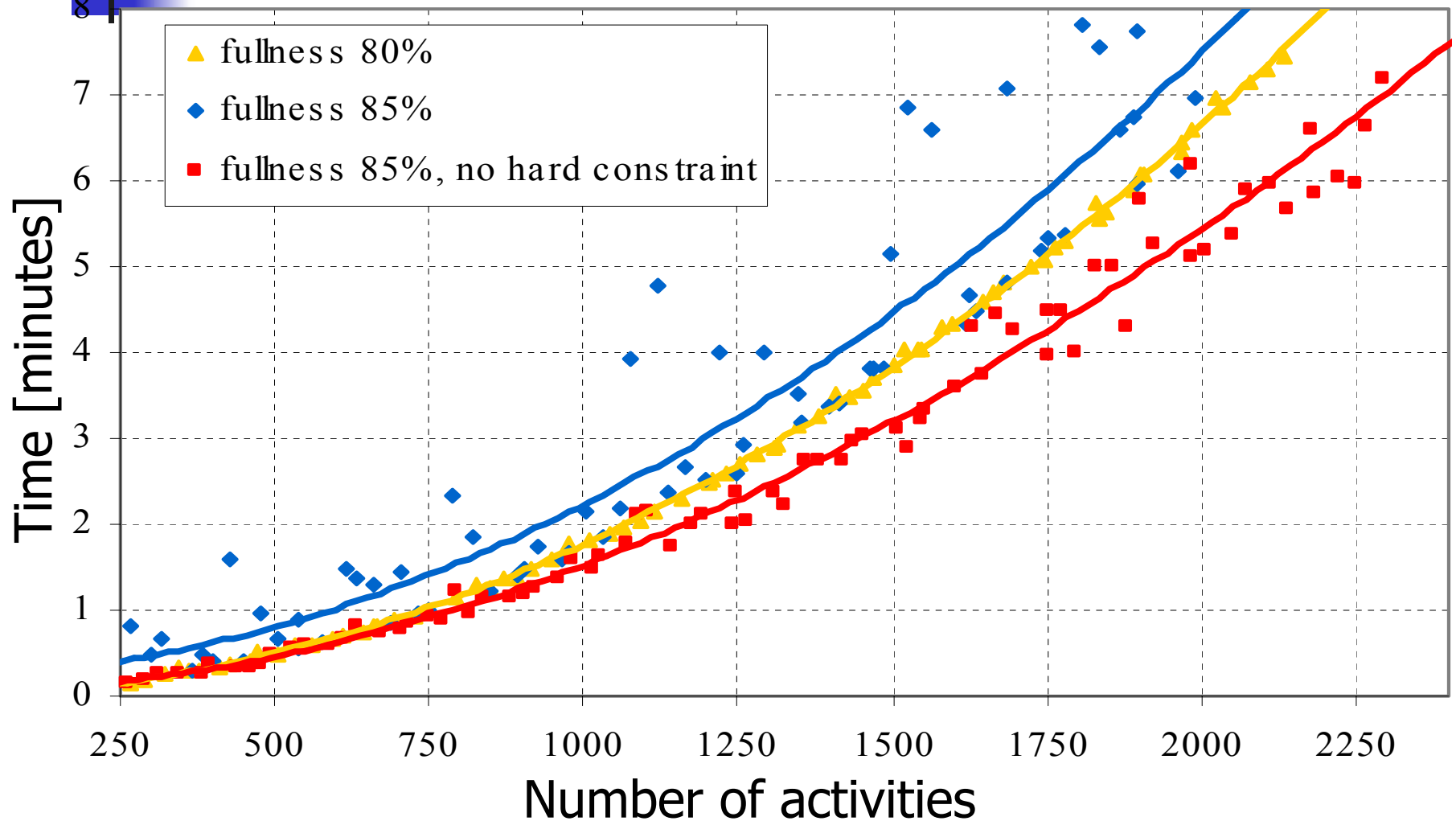
Practical Results:

Faculty of Mathematics and Physics

■ Solution:

- all activities scheduled – all hard constraints satisfied
- 76 crossovers for classes, 7 for teachers
- 21 classes with more than 10 hours a day, one class with more than 6 hours without a brake
- alternative lectures: a class could attend on average 84% of all alternatives
- 74 % of lectures scheduled from 9:00 to 16:25 (3rd-11th slot)
- 87% of lectures scheduled from 8:10 to 17:15 (2nd-12th slot)
- only 3% of lectures scheduled after 18:10 (14th slot) or after 14:50 (10th slot) on Fridays

Randomly generated timetable problems: Comparison of the time spent on solving the problem and the size of the problem





Conclusions

- Current Implementation
 - JAVA, several independent modules
 - general scheduling engine
 - activity & location selection criteria
 - GUI - school timetable
 - very promising results
 - easily extensible
 - new constraints, dependencies between activities, ...
 - generalizable to other constraint satisfaction problems

Timetable

Resources Lectures **Timetable**

Whole timetable Timetable of individual resources Rules

Not scheduled lectures:

Resource:

| Short cut | Name | Short cut | Name | Preferred | Forbidden | Note |
|-----------|------|-------------|------------------|---|-----------|-------------|
| | | FB/1-Y/28/A | Fyzika Bc. 1. r. | Mo 1-15,Tu 1-15,We 1-15,Th 1-15,Fr 1-15 | | FB/1-Y/28/A |
| | | FB/1-Y/28/B | Fyzika Bc. 1. r. | Mo 1-15,Tu 1-15,We 1-15,Th 1-15,Fr 1-15 | | FB/1-Y/28/B |
| | | FB/2/28/A | Fyzika Bc. 2. r. | Mo 1-15,Tu 1-15,We 1-15,Th 1-15,Fr 1-15 | | FB/2/28/A |
| | | FB/2/28/B | Fyzika Bc. 2. r. | Mo 1-15.Tu 1-15.We 1-15.Th 1-15.Fr 1-15 | | FB/2/28/B |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|----|-----------------------------|---|------------------------------|---|------------------------------|-----------------------------|------------------------|------------------------------------|---|-----------------------------|----|----|----|----|----|
| Mo | PRF033p1b c{00816} E5 | | PRF033x1k c{50305} E4 | | | PRF010x1a c{00808} T1 | | JAZ055x1a c{00665, 00799} T1 | | MAF033p2b c{00300} E1 | | | | | |
| Tu | | | OFY037p1a c{00773} KFK | | OFY037x1a c{00274} KFK | | | JAZ058x2b c{} K10 | | OFY021p1b c{} K4 | | | | | |
| We | | | TVY001x1a c{00836} KTV | | | | | ALG003p2a c{00029} K11 | | MAA007p2a c{00248} K8 | | | | | |
| Th | | | MAF033p1b c{00300} F2 | | OFY037p2a c{00773} KFK | | JAZ058x1b c{} M1 | | | OFY021p2b c{} M3 | | | | | |
| Fr | MAA007x1a c{00248} K8 | | ALG003p1a c{00029} K7 | | MAA007p1a c{00248} K7 | | | | | | | | | | |

Add a new lecture Solve State:

Timetable

Resources Lectures **Timetable**

Whole timetable Timetable of individual resources Rules

Not scheduled lectures:

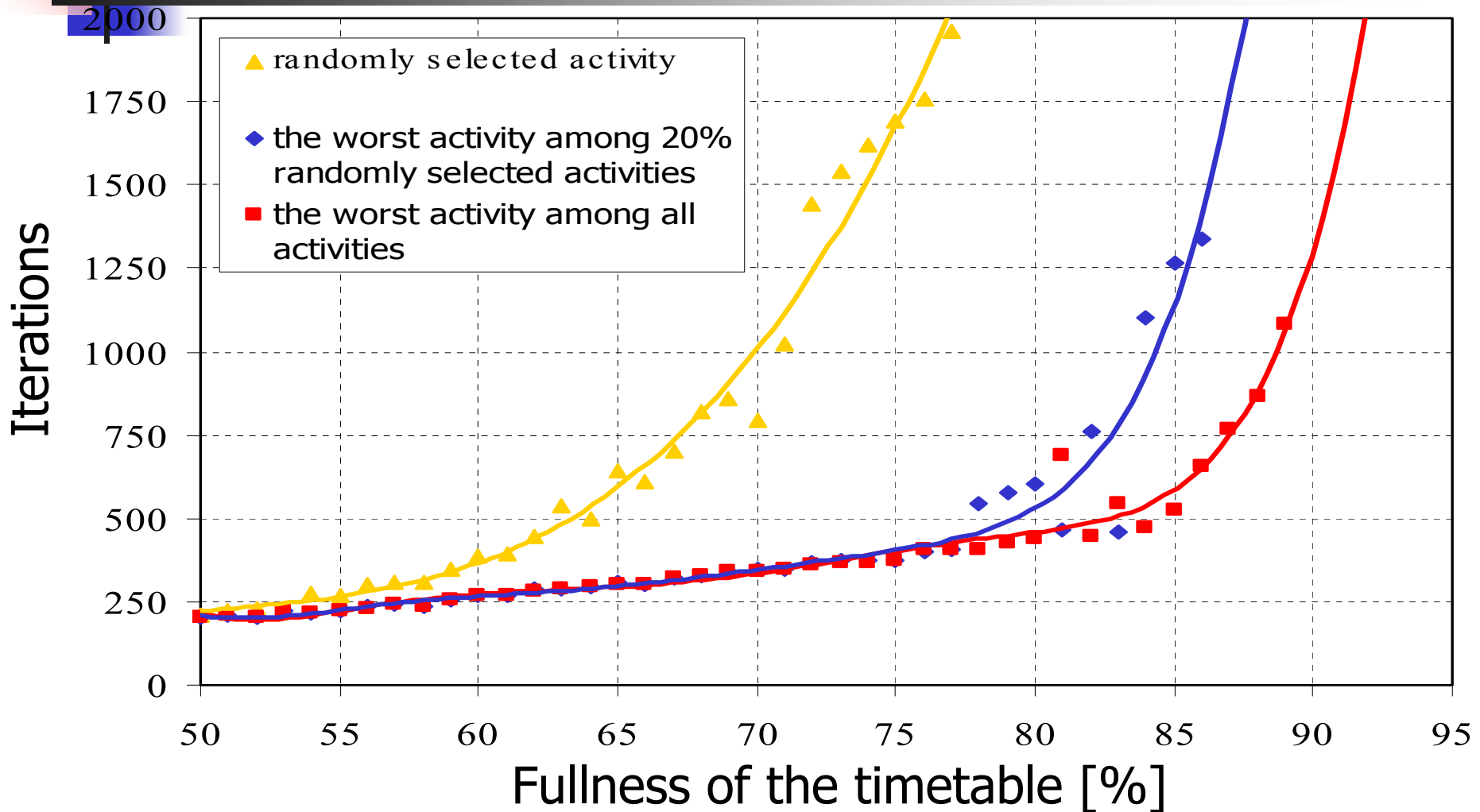
Resource:

| Short cut | Name | Short cut | Name | Preferred | Forbidden | Note |
|-----------|--------------------|---|------|-----------|-----------|------|
| K10 | K10 (Sokolovsk... | Mo 1-15,Tu 1-15,We 1-15,Th 1-15,Fr 1-15 | | | K,30 | |
| K11 | K11 (Sokolovsk... | Mo 1-15,Tu 1-15,We 1-15,Th 1-15,Fr 1-15 | | | K,35 | |
| K12 | K12 (Sokolovsk... | Mo 1-15,Tu 1-15,We 1-15,Th 1-15,Fr 1-15 | | | K,20 | |
| K2 | K2 (Sokolovská ... | Mo 1-15,Tu 1-15,We 1-15,Th 1-15,Fr 1-15 | | | K,45 | |

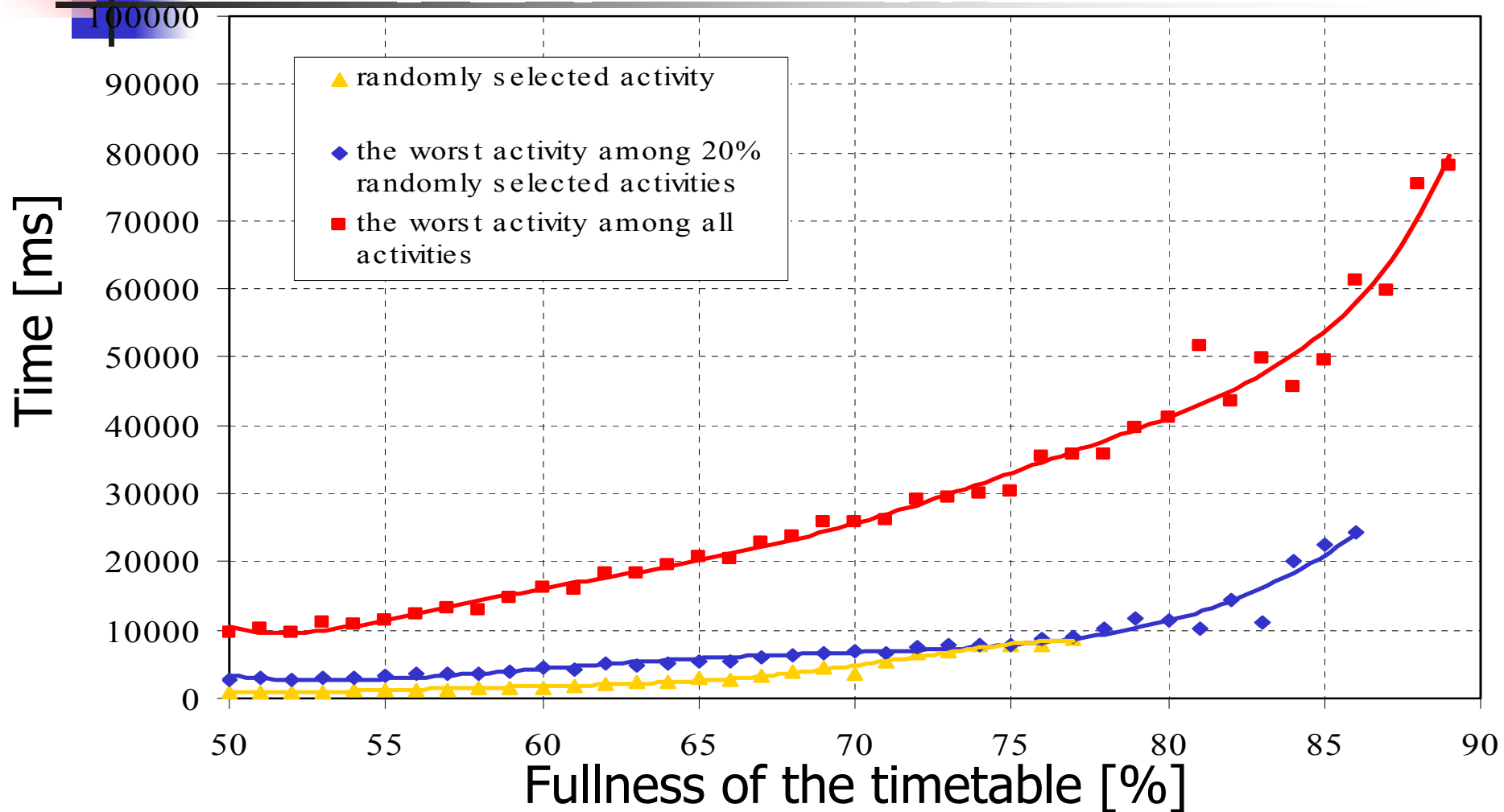
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|----|---|--|--|---|---|---|---|--|---|---|---|--|---|----|----|
| Mo | | | FAP034p1a c{M/5/FPM} c{00506} | | | MOD036p11 c{F/4/MOD, M/4/MO c{50015} | | MAA009x1a c{M/4/MA, M/3/MA} c{50300, 00485, 00 | | MOD013x11 c{F/4/MOD, M/4/MO c{00497} | | PRM024p1a c{OSTATNI} c{00838} | | | |
| Tu | | DMI002x1p c{I/1-Z/46/A, I/1-Z/46 c{} | MAI043p1c c{I/1-Z/43/A, I/1-Z/43 c{} | | | UMP012p1a c{PRFTV/UM/3/BI, F c{00868} | | MAI008x1m c{I/1-Z/43/A, I/1-Z/43 c{00120} | | MUE007x1b c{PRFTV/UM/2/BI, F c{00425} | | EKN022x1a c{MB/2/68/A, MB/2/6 c{00874} | | | |
| We | GEM002p1a c{F/3/MOD, M/3/EK, c{00063} | | MUE013p1a c{PRFTV/UM/3/BI, F c{00868} | | EKN011x1b c{M/3/EK, M/3/MMN, c{00467} | | MAI008x1b c{I/1-X/32/A, I/1-X/32 c{00225} | | MOD012p1a c{F/3/MOD, M/3/MO c{00413} | | FAP019p1a c{M/3/FPM, M/4/FPM c{00777} | | FAP016x1b M/4/FPM c{00839} | | |
| Th | FAP017x1a c{M/4/FPM, M/3/FPM c{00524} | | STP097x1b c{M/3/FPM, M/3/MMN c{00080} | | UMP011p1a c{PRFTV/UM/3/BI, F c{00042} | | DMI026x c{I/2/36/A c{} | | STP094p1a c{M/4/EK, M/4/MMN, c{00924} | | STP026x1a c{M/4/EK, M/4/MMN, c{00161} | | UMP008p1a c{PRFTV/UM/2/BI, F c{00066} | | |
| Fr | MAF033x1d c{F/1-X/14/A, F/1-X/14 c{00729} | | PRM001x1j c{M/1-Y/60/A, M/1-Y c{00871} | | STP026p1a c{M/4/EK, M/4/MMN, c{00303} | | | | MAA021x1a c{M/3/EK, M/3/FPM, c{00473} | | | | | | |

Add a new lecture Solve State:

Comparison of the number of iterations for three basic variable selection criteria



Comparison of the time for three basic variable selection criteria



Comparison of the number of scheduled activities for three basic variable selection criteria

