Minimal Perturbation Problem in Course Timetabling

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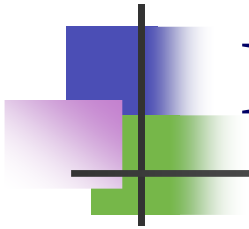
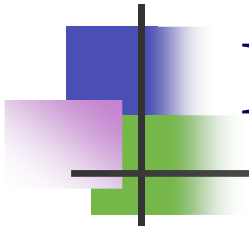


Motivation [1]

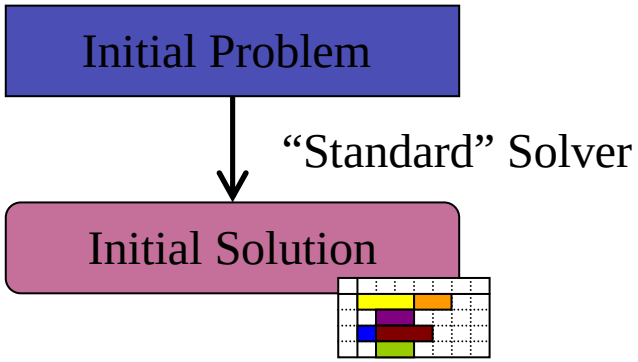
- Minimal Perturbation Problem
  - Problem definition can vary in time
    - Environment changes
      - broken machines, delayed flights, ...
    - New properties based on a solution found so far



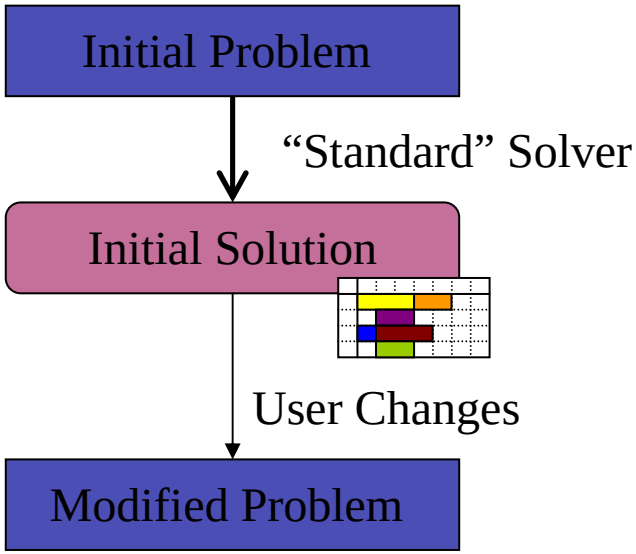
Motivation [1]

- Minimal Perturbation Problem
  - Problem definition can vary in time
    - Environment changes
      - broken machines, delayed flights, ...
    - New properties based on a solution found so far
  - Goal
    - Adopted solution should differ as little as possible
      - Solution may be already published
      - New changes may necessitate other changes
      - …

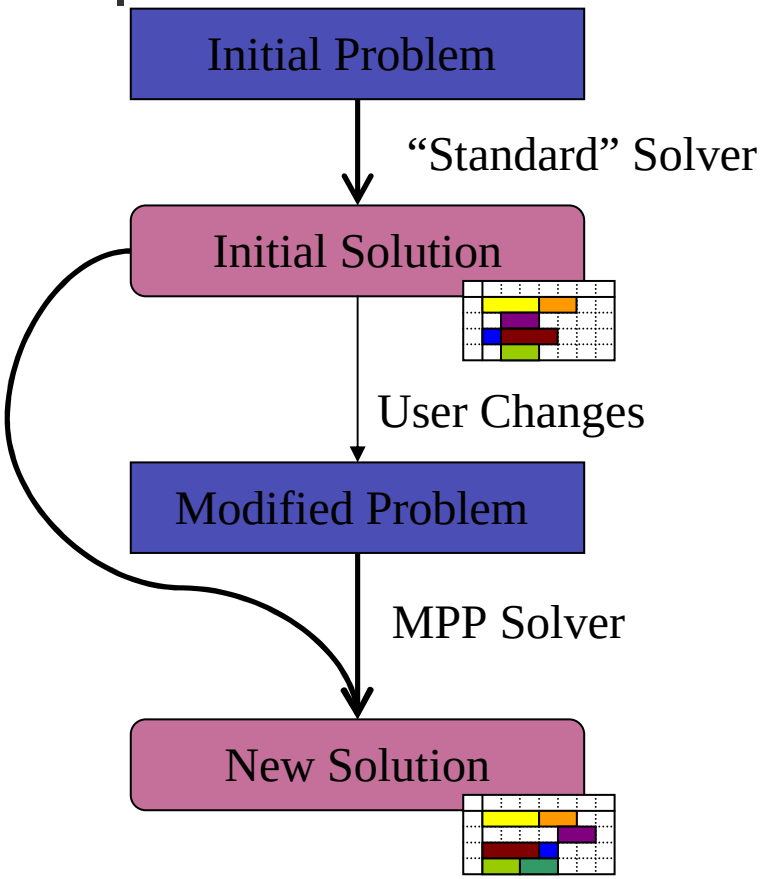
Minimal Perturbation Problem



Minimal Perturbation Problem



Minimal Perturbation Problem



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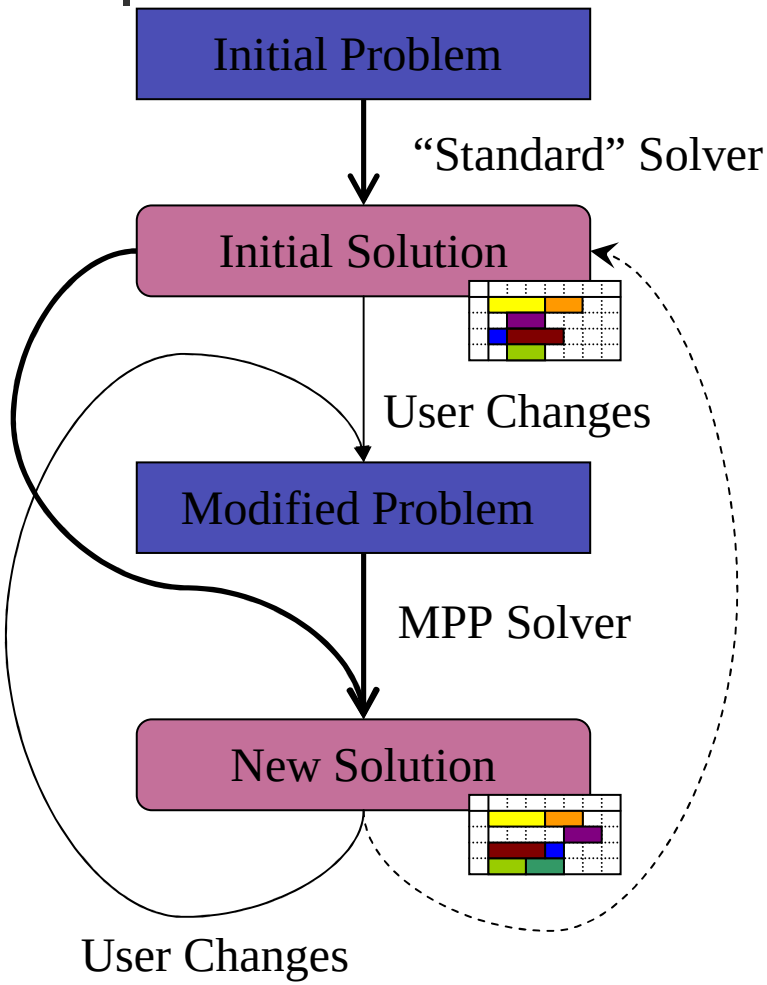

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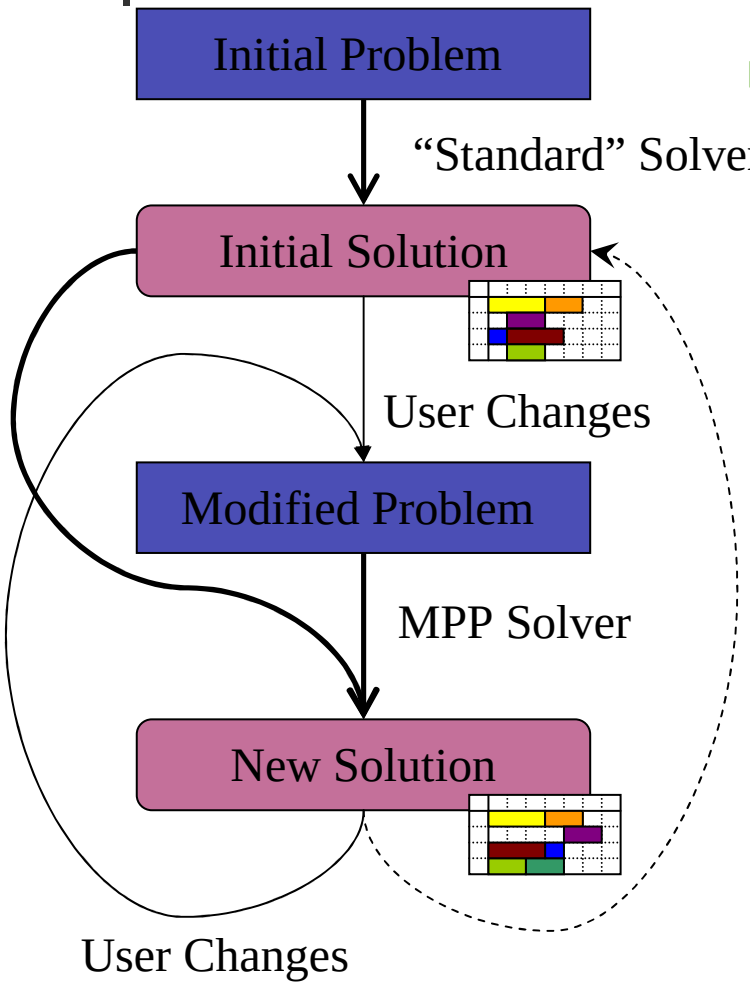

- MPP Solver
  - Input
    - Initial Solution
    - Problem
  - Output
    - New Solution
      - Solving given problem
      - As near as possible to the initial solution
  - Metrics
    - Number of perturbations
      - Number of differently assigned variables
      - Number of classes scheduled in different time
      - Number of affected teachers or students
      - …

Motivation [2]

- Timetabling Problem at Purdue University
  - Central timetable for large lecture classes
    - 830 classes, some of them (25%) with multiple sections
    - 50 lecture rooms (with various equipment, up to 474 seats)
    - 89,633 course demands from 29,808 students
    - Utilization over 78% (~ 94% for the four largest rooms)
  - Timetables for individual departments
    - Done manually for the moment
      - An area for our future work

Fall 2004

Purdue University Timetabling

- For each class
  - Student requirements
  - Time requirements & preferences
    - Meeting patterns (e.g., 3 x 50 min, 2 x 75 min)
  - Room requirements & preferences
    - Capacity
    - Required equipment
    - Room / building preference
  - Instructor
  - Additional (group) constraints
    - Between several classes (e.g. back-to-back, precedence)
  - Other …

Each student states which courses he or she wants to attend (soft constraint)

Purdue University Timetabling

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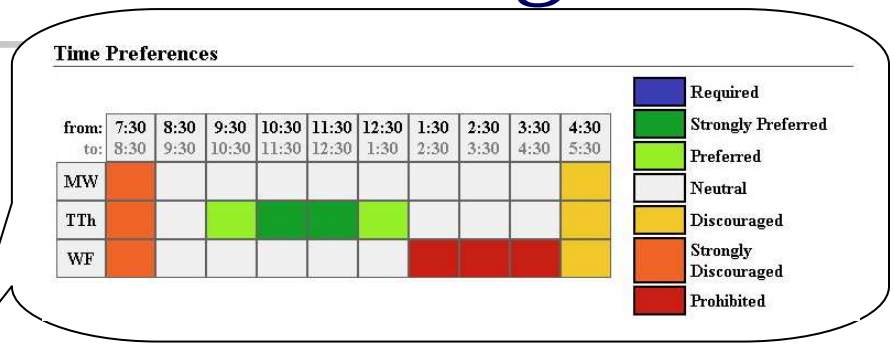

Purdue University Timetabling

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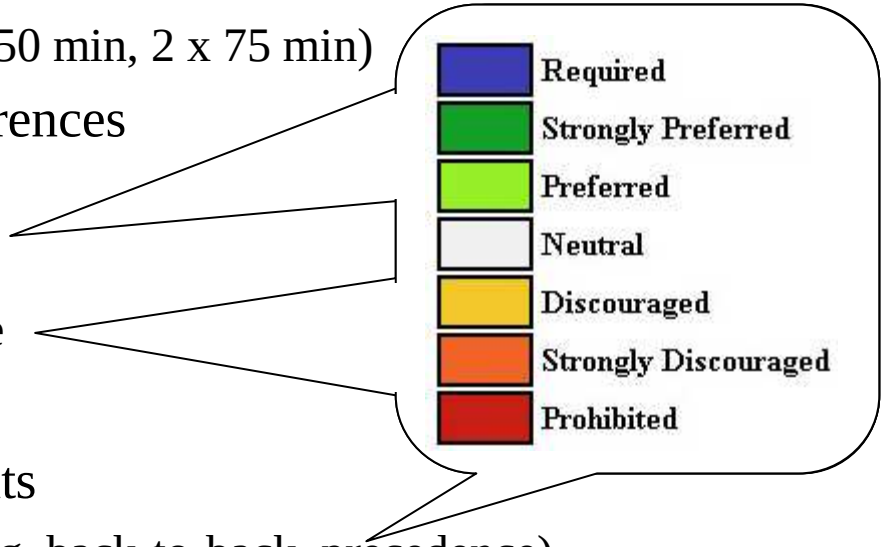
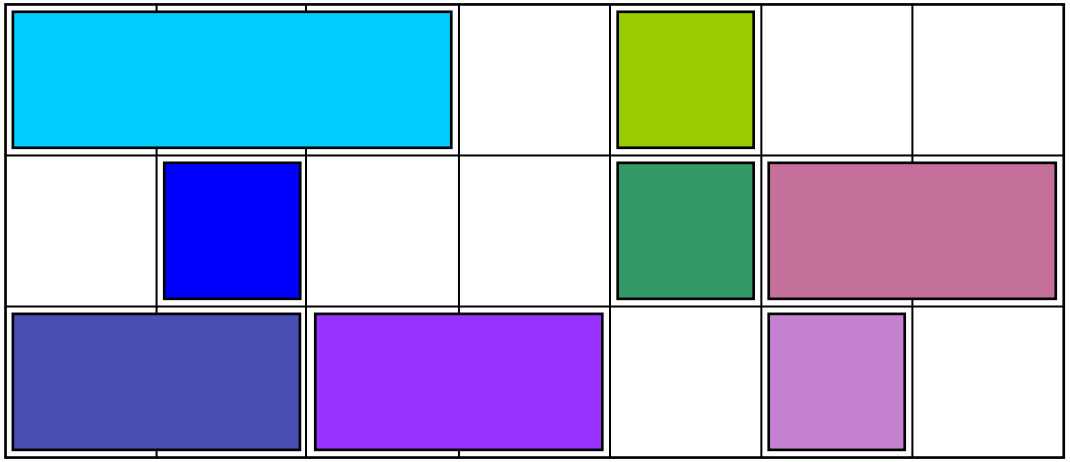
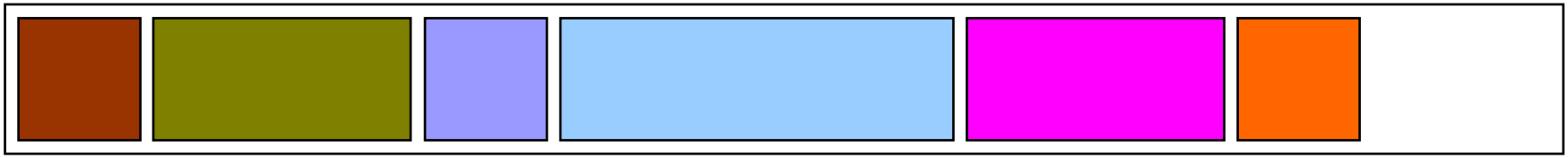


Iterative Forward Search Algorithm

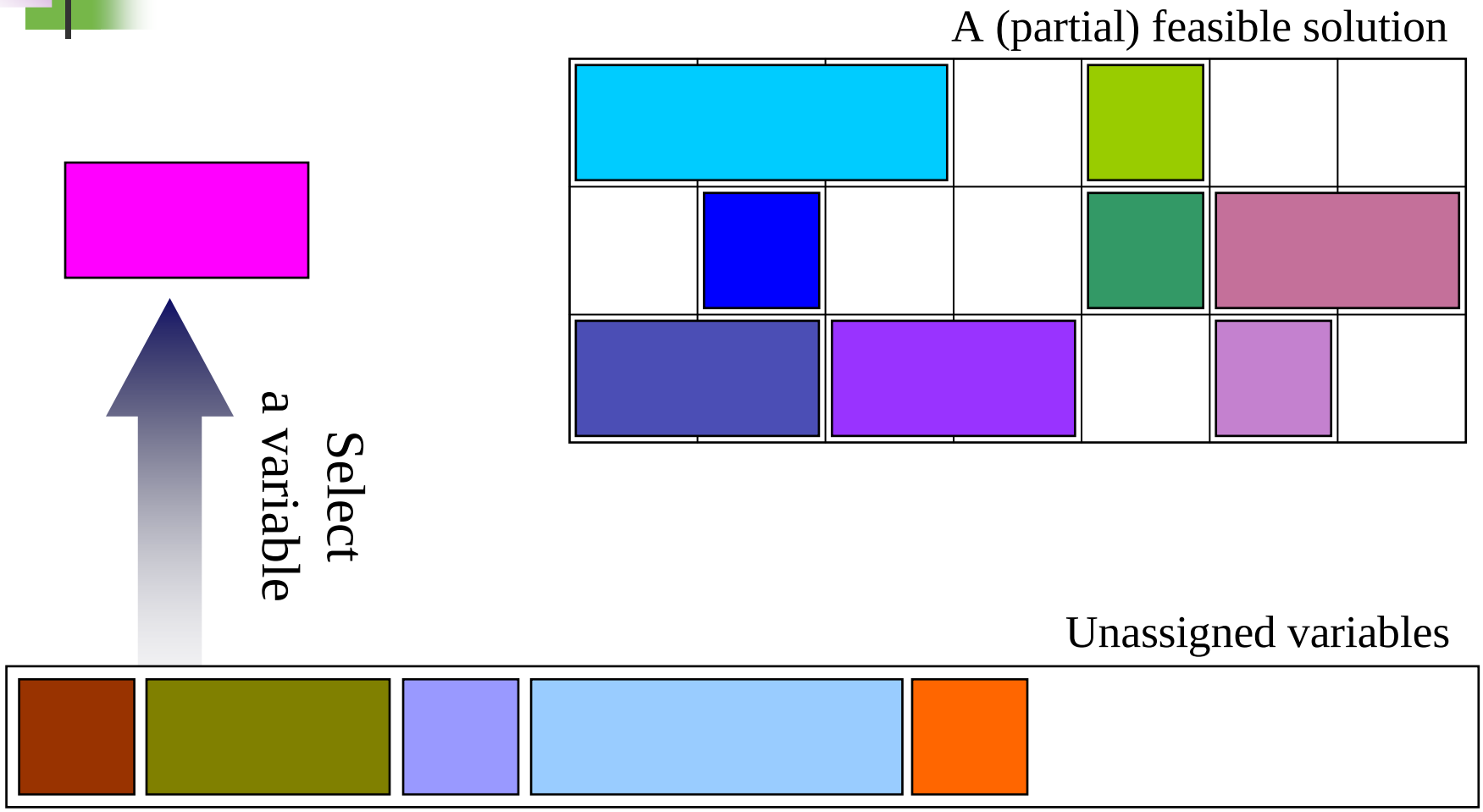
A (partial) feasible solution



Unassigned variables



Iterative Forward Search Algorithm



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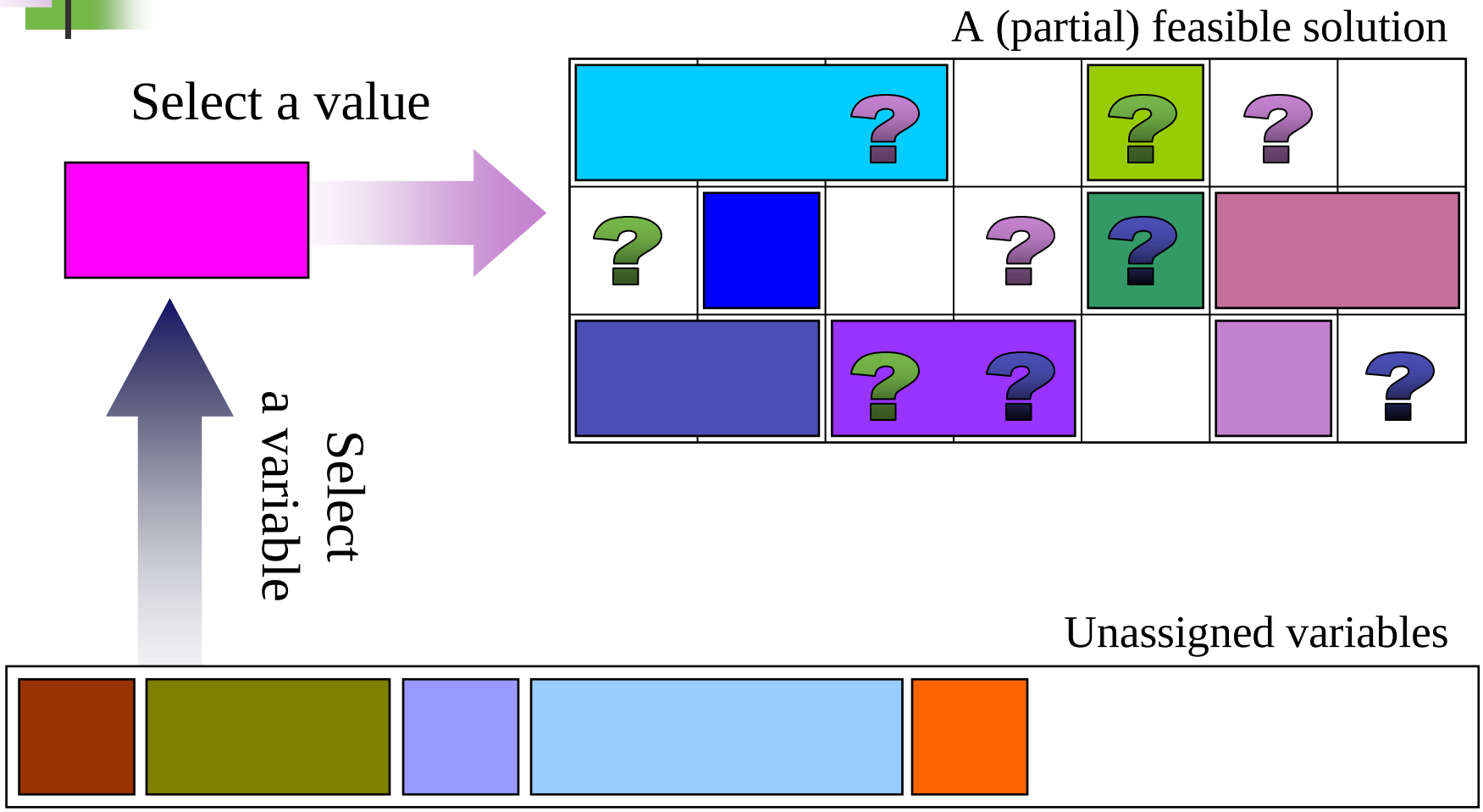

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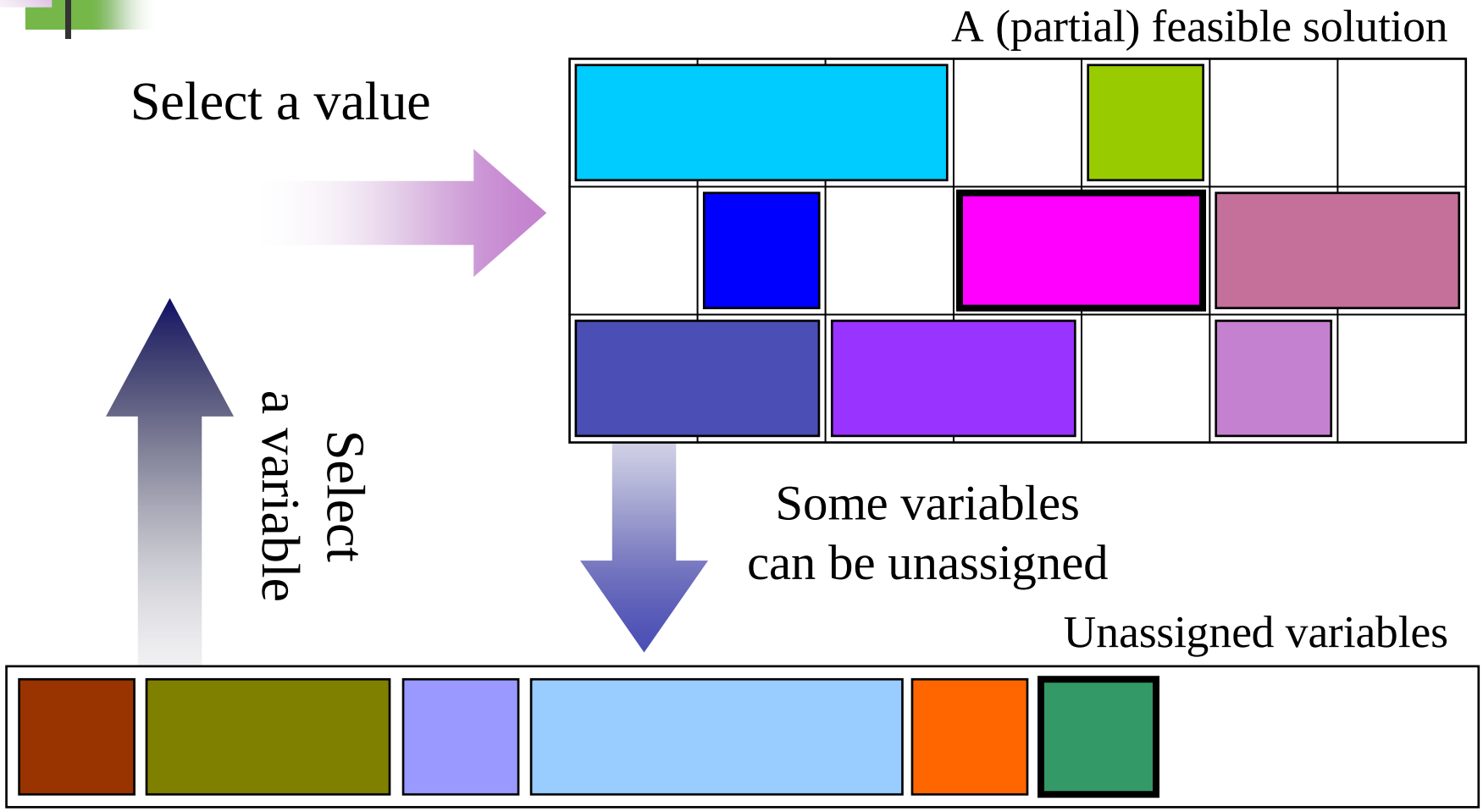
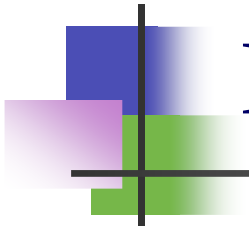


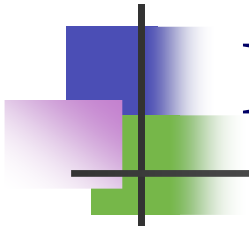


Iterative Forward Search Algorithm

- Variable selection
  - A weighted sum of
    - Variable domain size
    - Number of previous assignments
    - Number of participating constraints
    - …
  - All variables might be assigned
    - The worst variable in the sense of soft constraint
    - MPP: A variable which has assigned a different value than in the initial solution
  - Not so important as value selection

Iterative Forward Search Algorithm

- Value selection
  - MPP: Initial value is selected with a given probability
  - MPP: Number of additional perturbations is limited
  - Weighted sum of
    - Number of hard conflicts
    - Soft conflicts
  - Moreover: Three levels of weighted sums
    - Violated hard constraints
    - Important soft constraints
    - Other soft constraints



Iterative Forward Search Algorithm

- Termination condition
  - Solution is complete and good enough
    - Expressed as a number of perturbations and a weighted sum of violated soft constraints
  - Timeout or user intervention
- Solution comparator: better solution has
  - Less unassigned variables
  - MPP: Smaller number of perturbations
  - Smaller weighted sum of violated soft constraints
    - Time and room preferences, soft group constraints, number of student conflicts

Conflict-based statistics

- Idea
  - Memorize conflicts and discourage their potential repetition

- If $A=a$ is unassigned because of the $B=c$
  - A counter Stat[$A\neq a$,$B=c$] is incremented

$$A \neq a \Leftarrow \begin{cases} 3 \times B = a \\ 4 \times B = c \\ 2 \times C = a \\ 120 \times D = a \end{cases}$$

Conflict-based statistics

To be used e.g. in value selection

- If a is being selected for variable A
- And there is $B=b$ in a conflict with $A=a$

Value a is weighted by Stat[$B\neq b$,$A=a$]+1

Conflicts are weighted by
their occurrences in the past

Experiments: Initial Problem

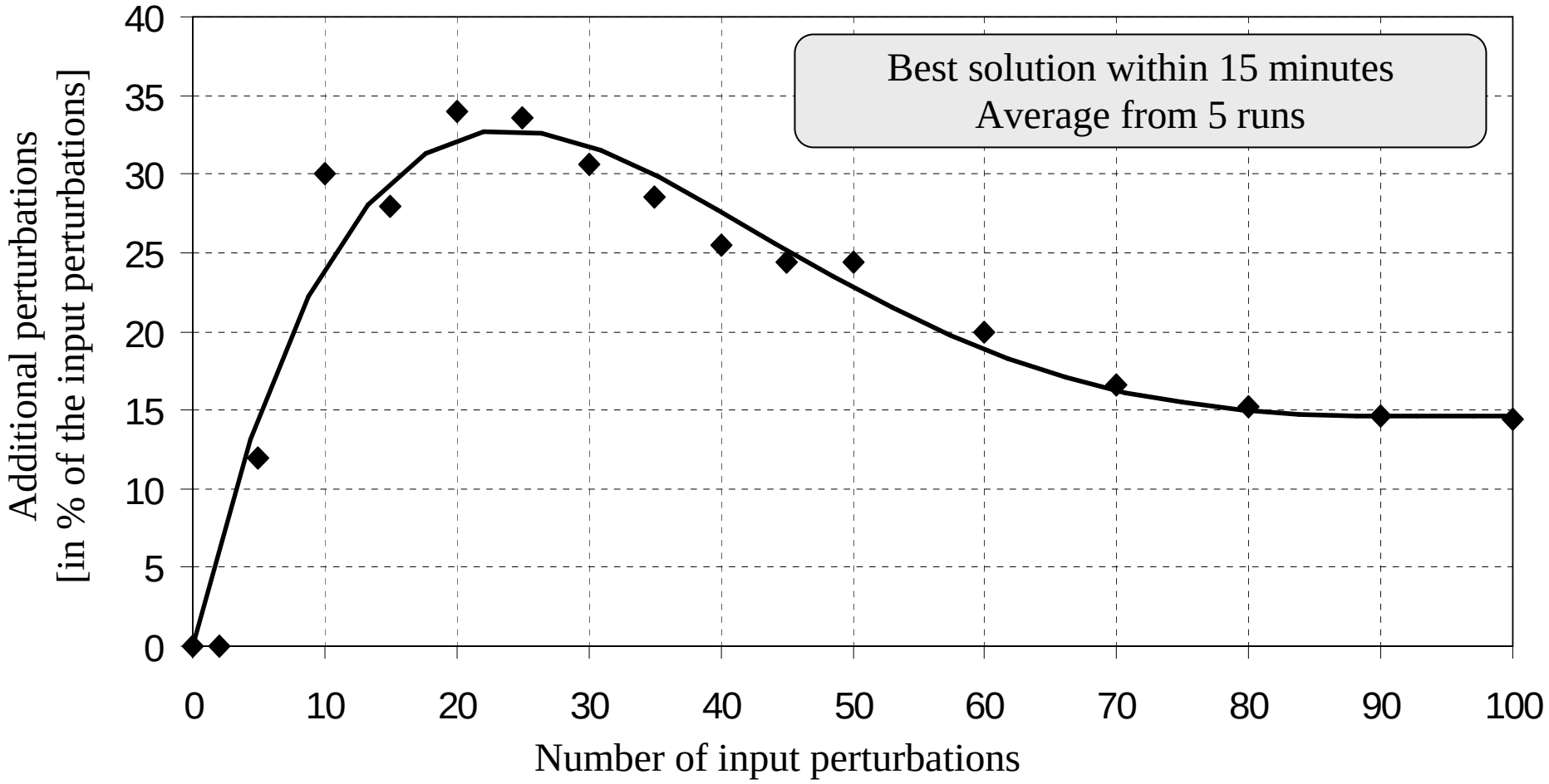
- Fall 2004 data set
- Best solution within 30 minutes, 10 runs
- 1GHz Pentium III, Java 1.4.2

Results from Fall 2001 are presented in the paper

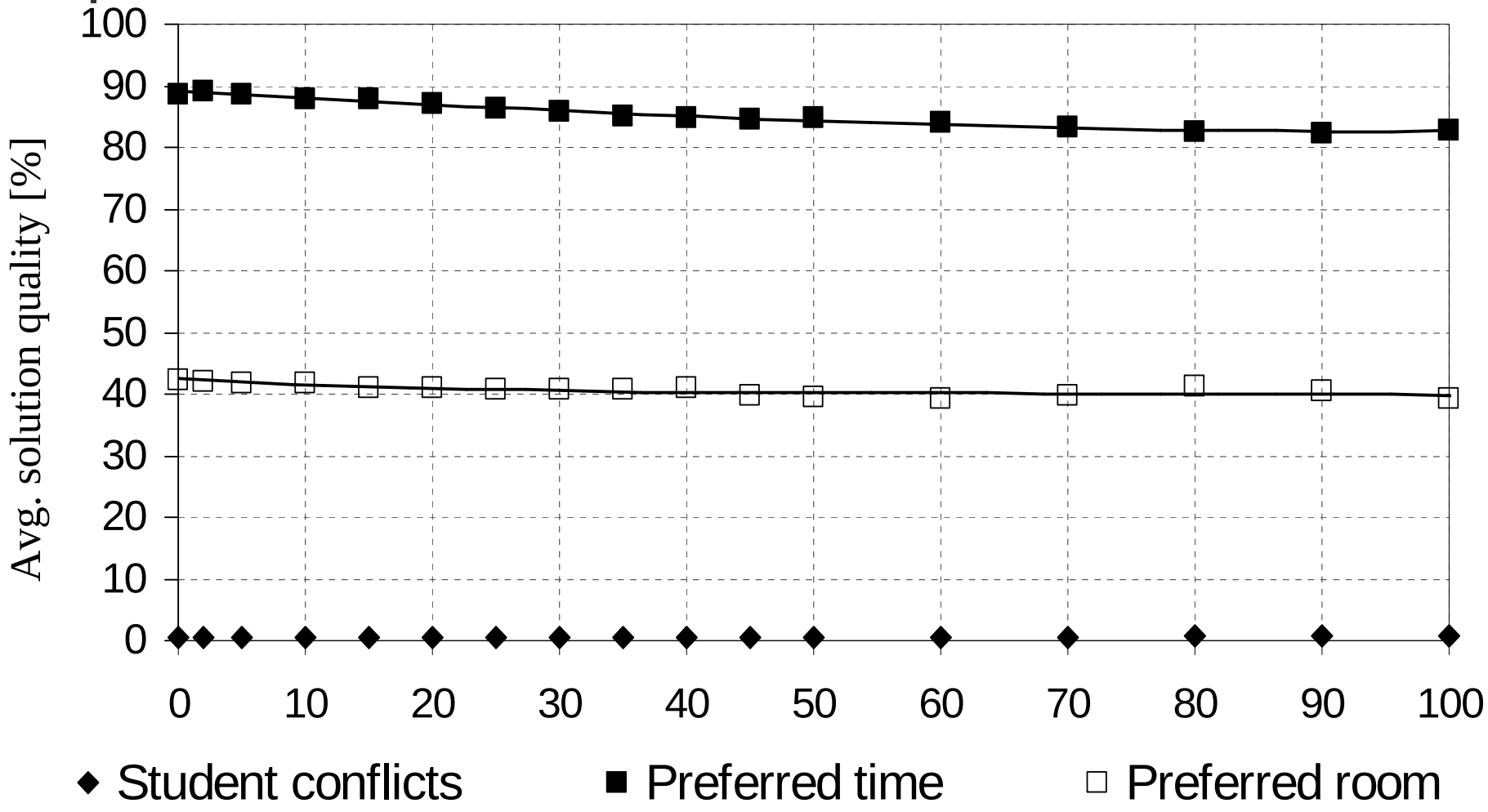
Test Case	With CBS	Without CBS
Assigned classes [%]	100.0 ± 0.00	98.42 ± 0.20
Time [min]	19.01 ± 6.70	24.08 ± 4.42
Student conflicts [%]	0.38 ± 0.03	0.49 ± 0.06
Preferred time [%]	81.49 ± 0.97	81.93 ± 1.45
Preferred room [%]	49.76 ± 7.88	51.10 ± 4.40

Still at least 5 unassigned classes after 3 hours

Experiments: Minimal Perturbation Problem



Experiments: Minimal Perturbation Problem



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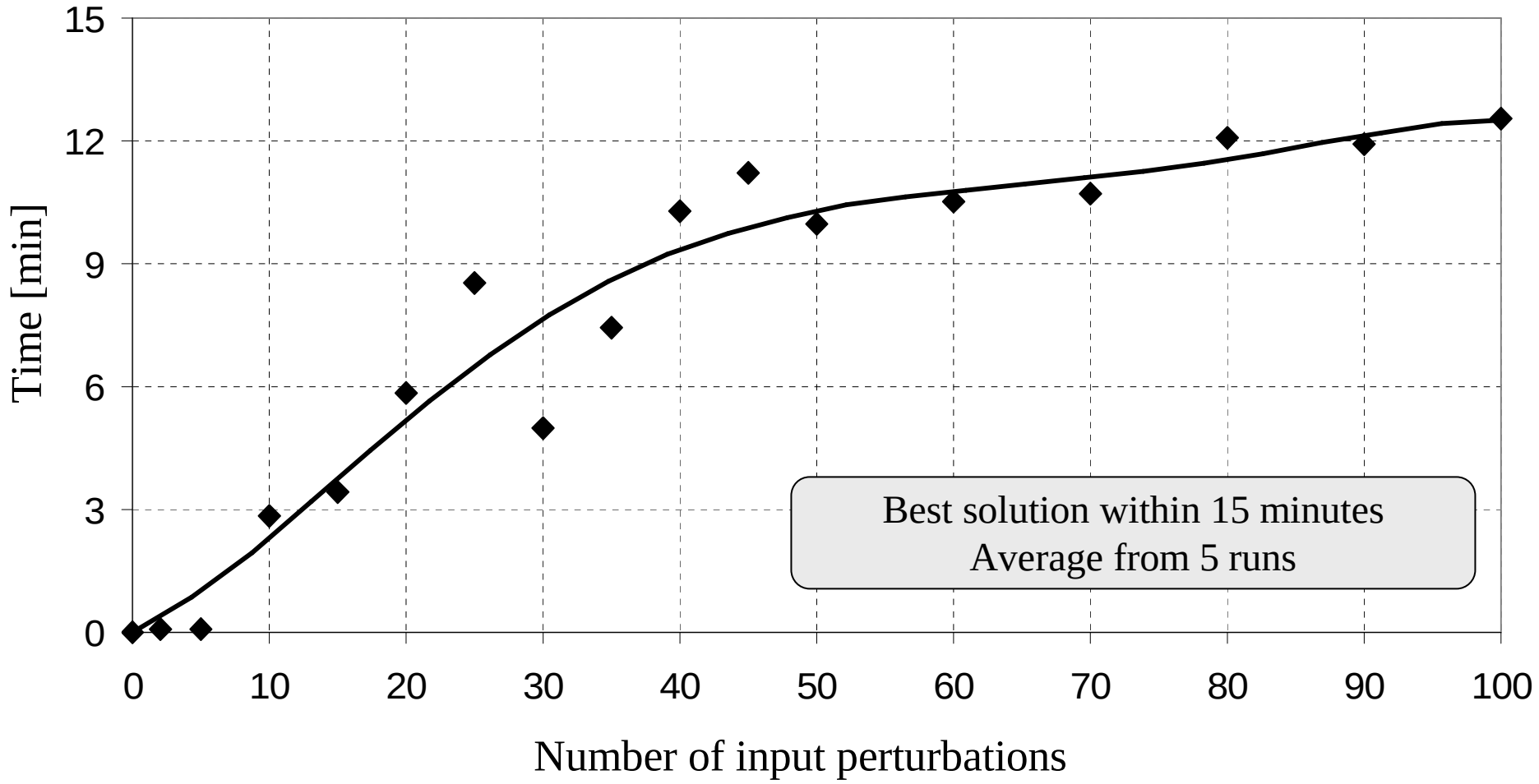

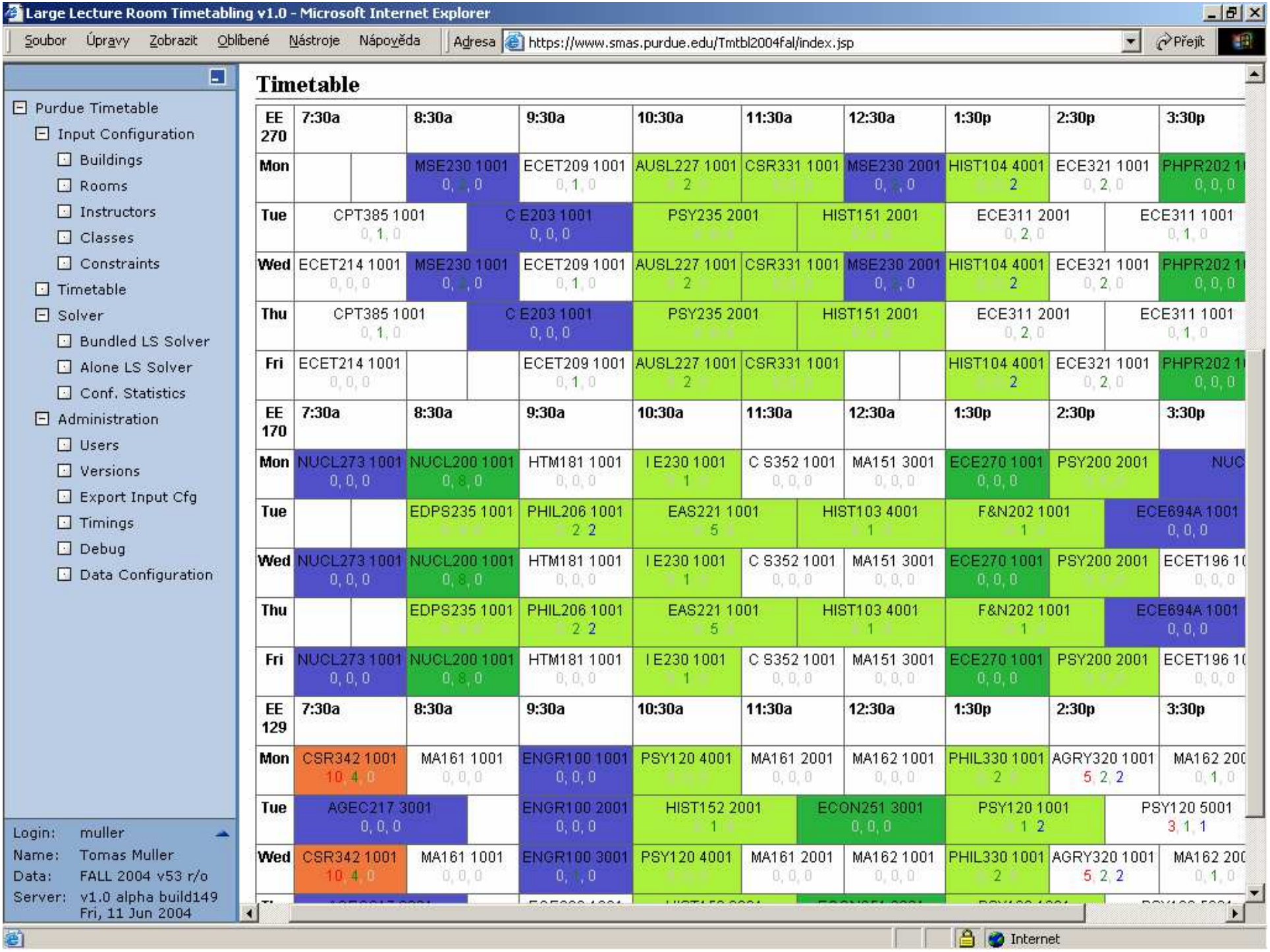
Large Lecture Room Timetabling v1.0 - Microsoft Internet Explorer
Soubor Úpravy Zobrazit Oblíbené Nástroje Nápověda
Adresa https://www.smas.purdue.edu/Tmtbl2004fal/index.jsp
Přejít
Purdue Timetable
Input Configuration
Buildings
Rooms
Instructors
Classes
Constraints
Timetable
Solver
Bundled LS Solver
Alone LS Solver
Conf. Statistics
Administration
Users
Versions
Export Input Cfg
Timings
Debug
Data Configuration
Login: muller
Name: Tomas Muller
Data: FALL 2004 v53 r/o
Server: v1.0 alpha build149
Fri, 11 Jun 2004
Timetable
EE 270
7:30a 8:30a 9:30a 10:30a 11:30a 12:30a 1:30p 2:30p 3:30p
Mon
MSE230 1001 0, 8, 0
ECET209 1001 0, 1, 0
AUSL227 1001 2
CSR331 1001
MSE230 2001 0, 8, 0
HIST104 4001 2
ECE321 1001 0, 2, 0
PHPR202 1 0, 0, 0
Tue
CPT385 1001 0, 1, 0
C E203 1001 0, 0, 0
PSY235 2001
HIST151 2001
ECE311 2001 0, 2, 0
ECE311 1001 0, 1, 0
Wed
ECET214 1001 0, 0, 0
MSE230 1001 0, 8, 0
ECET209 1001 0, 1, 0
AUSL227 1001 2
CSR331 1001
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ECE321 1001 0, 2, 0
PHPR202 1 0, 0, 0
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CPT385 1001 0, 1, 0
C E203 1001 0, 0, 0
PSY235 2001
HIST151 2001
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ECE311 1001 0, 1, 0
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ECET209 1001 0, 1, 0
AUSL227 1001 2
CSR331 1001
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ECE321 1001 0, 2, 0
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EE 170
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NUCL200 1001 0, 8, 0
HTM181 1001 0, 0, 0
I E230 1001 1
C S352 1001 0, 0, 0
MA151 3001 0, 0, 0
ECE270 1001 0, 0, 0
PSY200 2001
NUC
Tue
EDPS235 1001
PHIL206 1001 2 2
EAS221 1001 5
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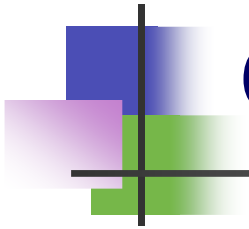

Conclusion And Future Work

- Iterative forward search algorithm with conflict-based statistics
  - Good results on Purdue University Problem
    - Both on initial and minimal perturbations problems
- Future work
  - More results
    - Timetables for individual departments
    - Other (not only timetabling) problems
  - Solver improvements
  - Additional requirements from Purdue University