



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

Initial Problem

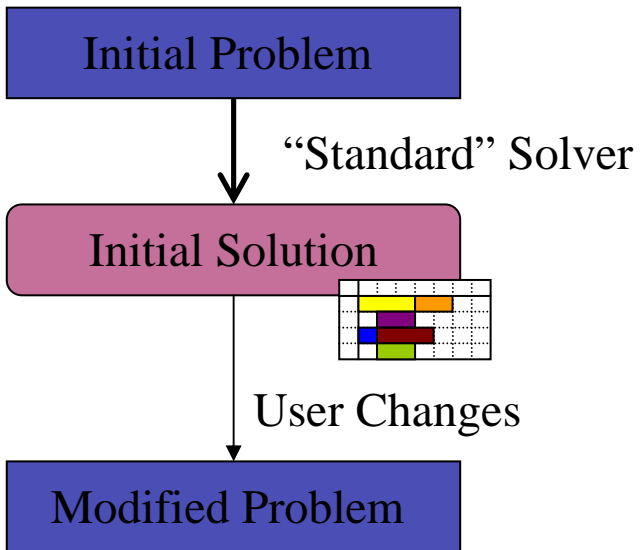


“Standard” Solver

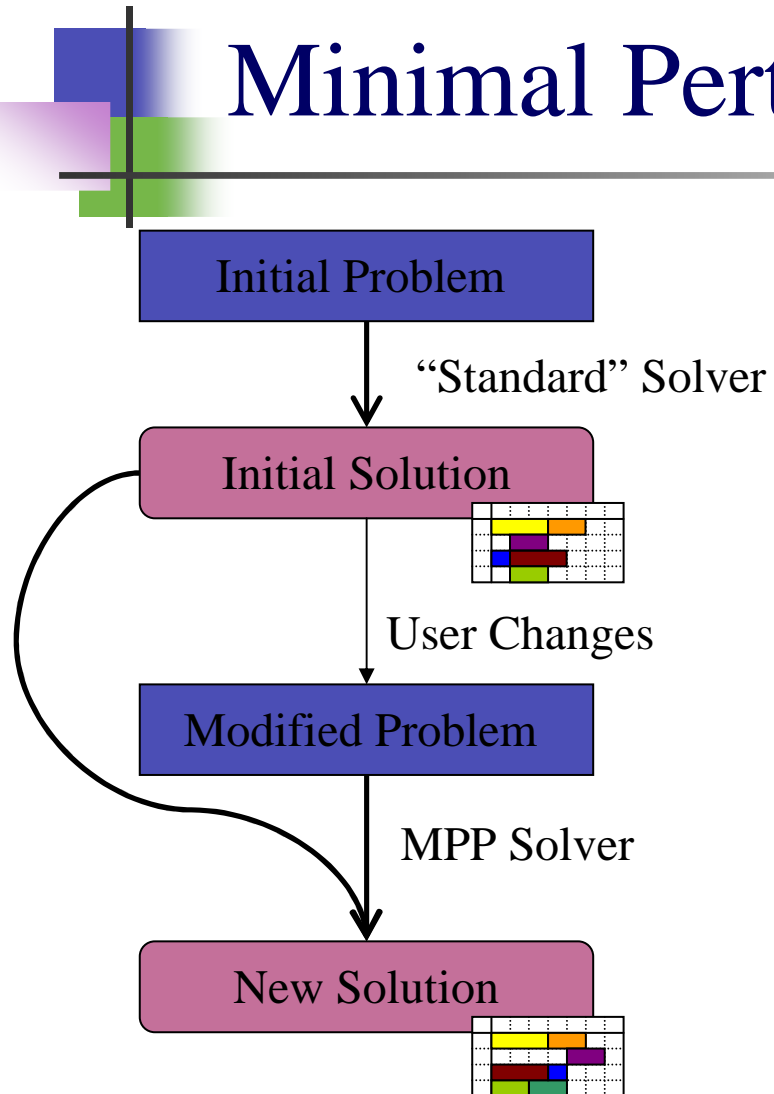
Initial Solution



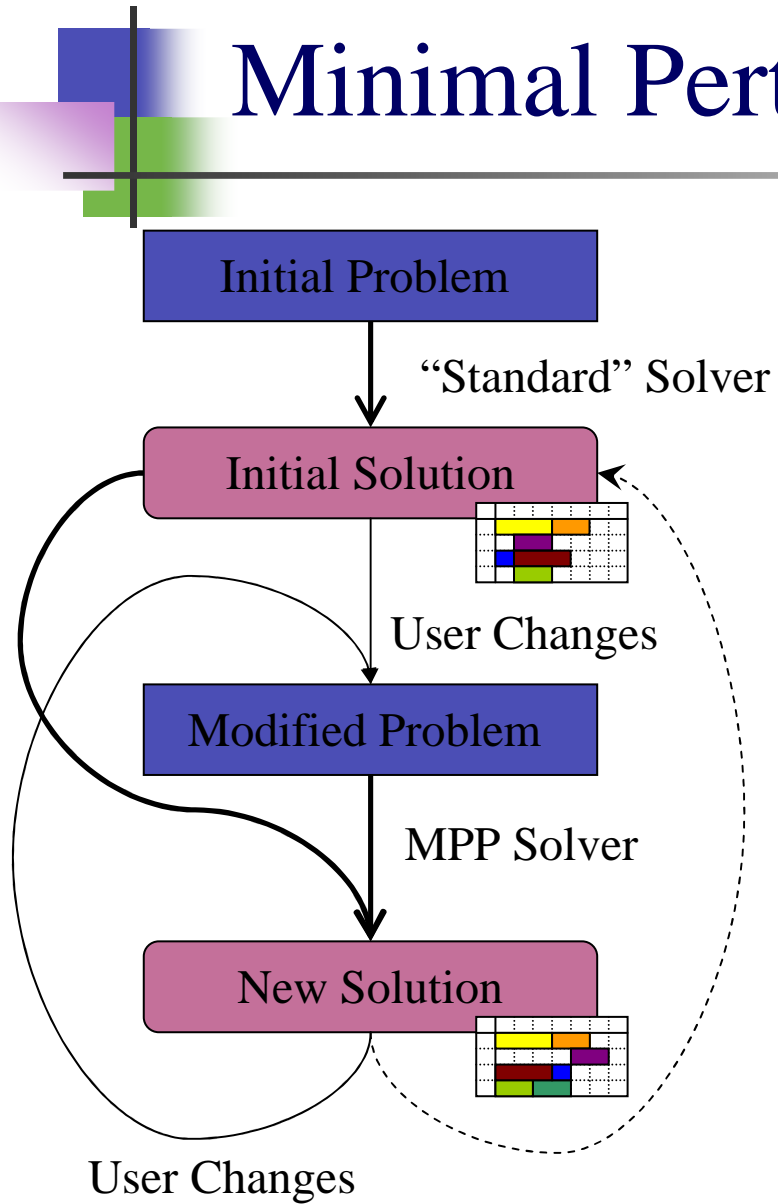
Minimal Perturbation Problem



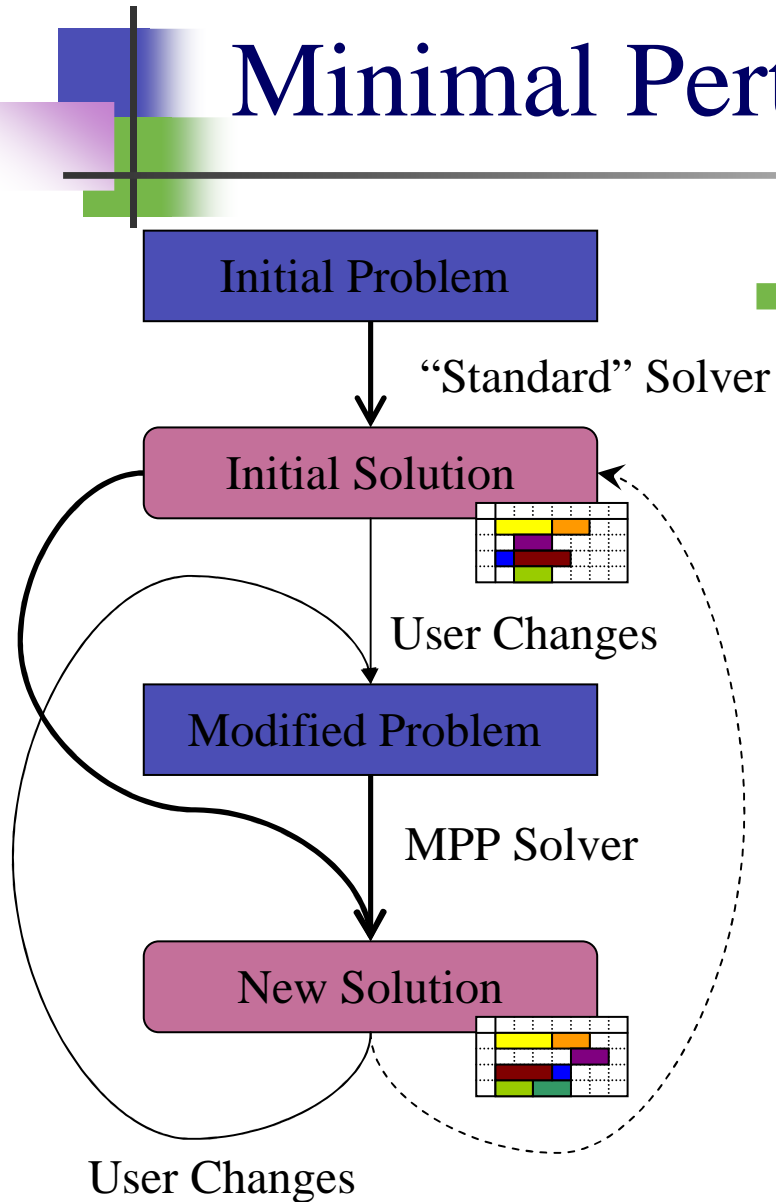
Minimal Perturbation Problem



Minimal Perturbation Problem



Minimal Perturbation Problem



■ 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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- Other ...

Time Preferences

from:	7:30	8:30	9:30	10:30	11:30	12:30	1:30	2:30	3:30	4:30
to:	8:30	9:30	10:30	11:30	12:30	1:30	2:30	3:30	4:30	5:30
MW	Strongly Discouraged	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Discouraged
TTh	Strongly Discouraged	Neutral	Preferred	Strongly Preferred	Strongly Preferred	Preferred	Neutral	Neutral	Neutral	Discouraged
WF	Strongly Discouraged	Neutral	Neutral	Neutral	Neutral	Neutral	Prohibited	Prohibited	Prohibited	Discouraged



Purdue University Timetabling

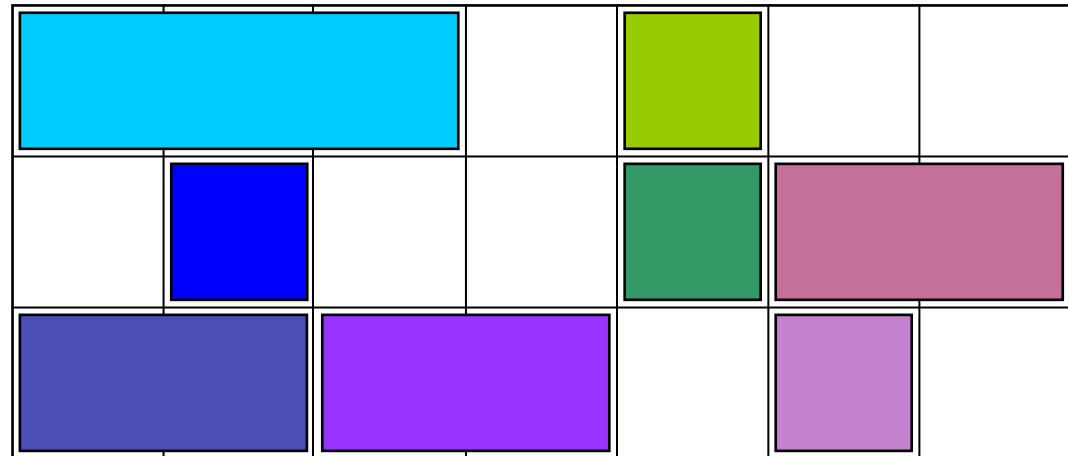
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Iterative Forward Search Algorithm

A (partial) feasible solution

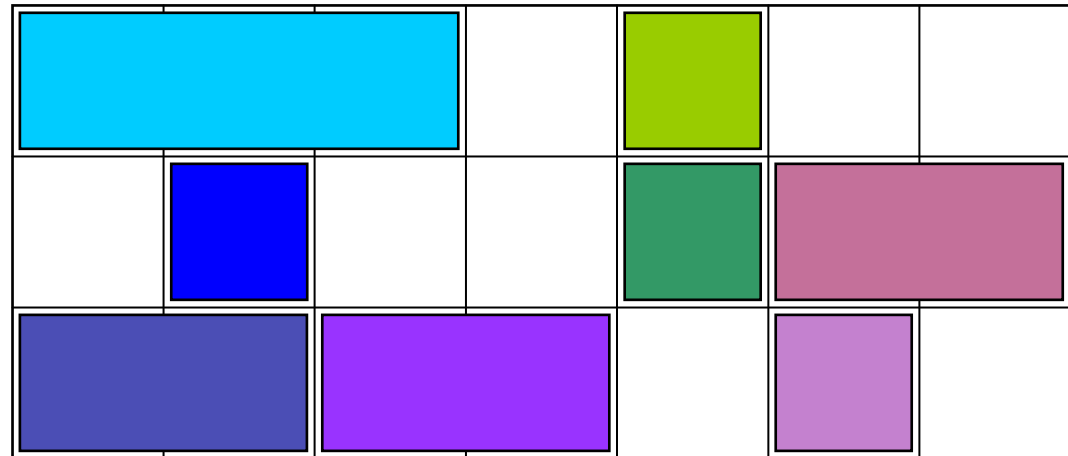


Unassigned variables

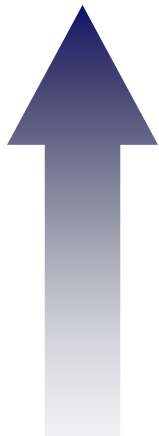
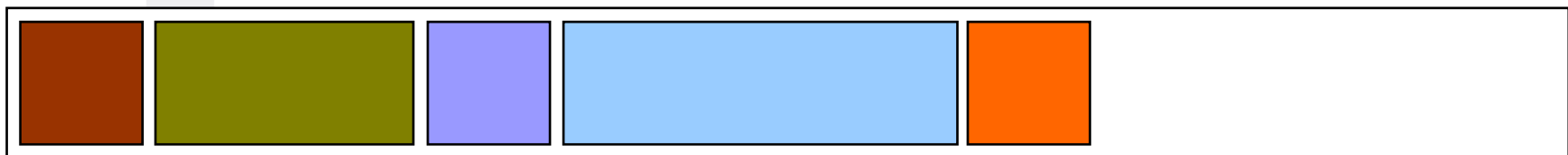


Iterative Forward Search Algorithm

A (partial) feasible solution

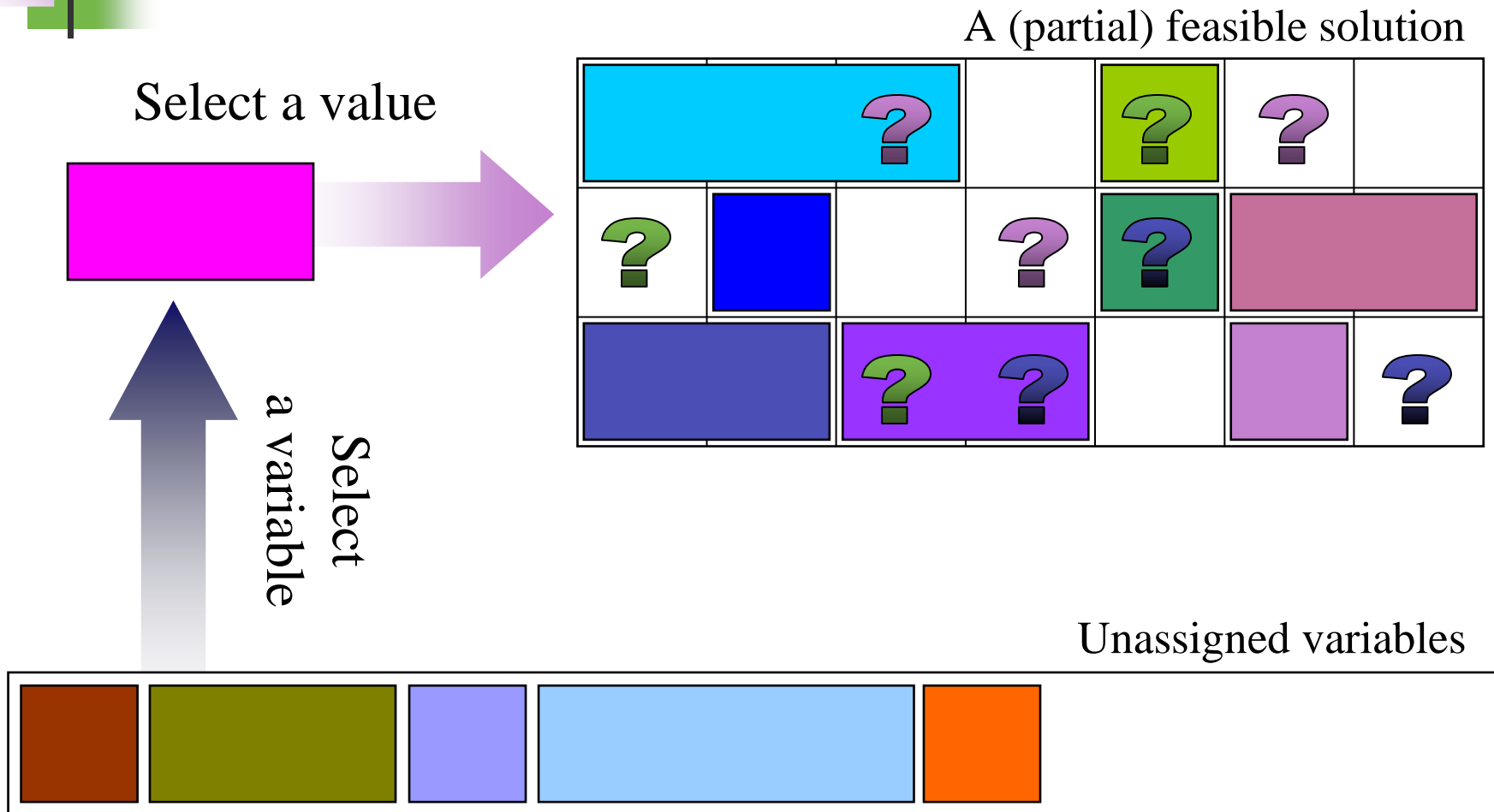


Unassigned variables

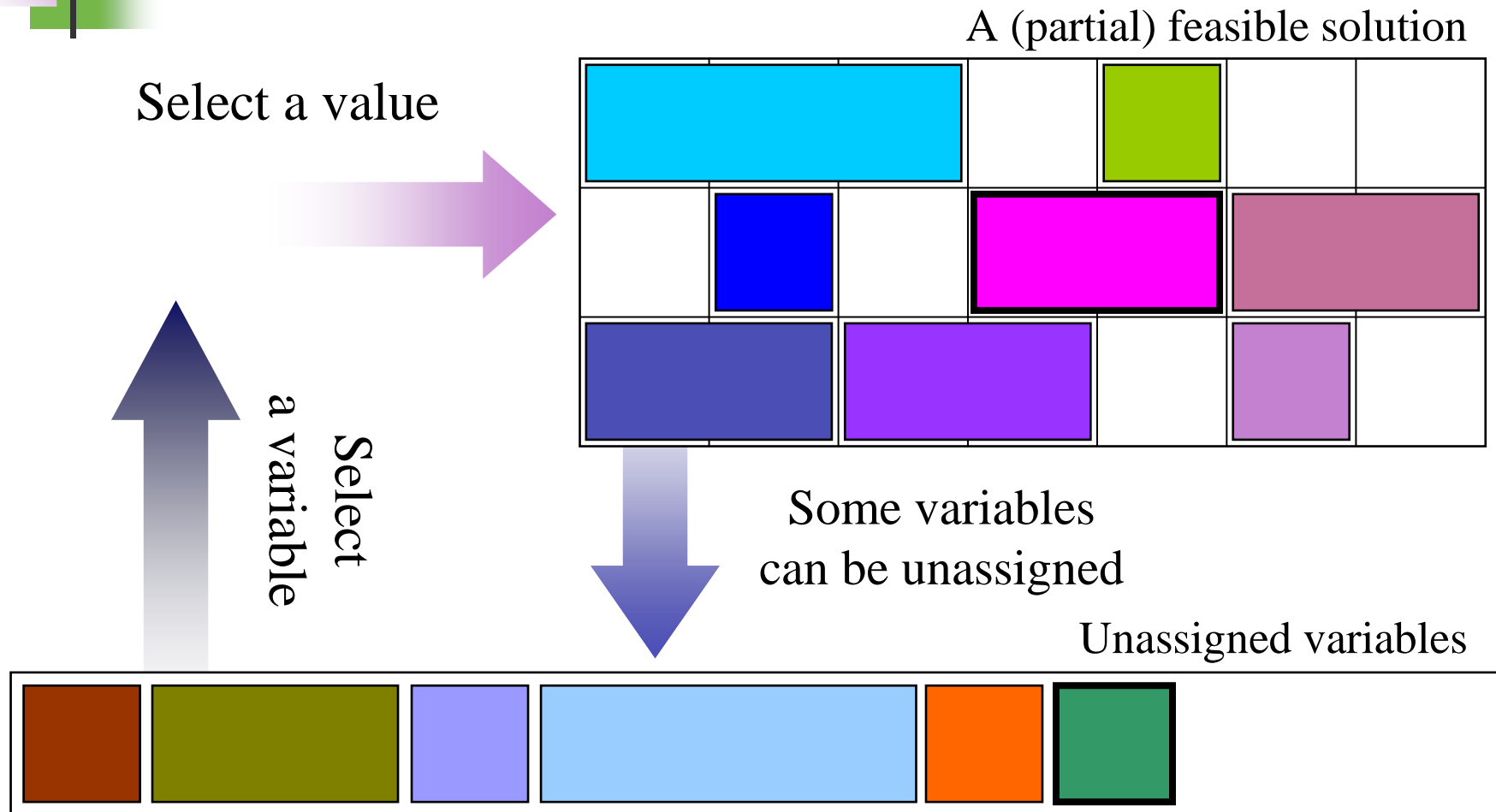


Select
a variable

Iterative Forward Search Algorithm



Iterative Forward Search Algorithm





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 $\text{Stat}[A \neq a, B=c]$ 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 $\text{Stat}[B \neq b, A = a] + 1$

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

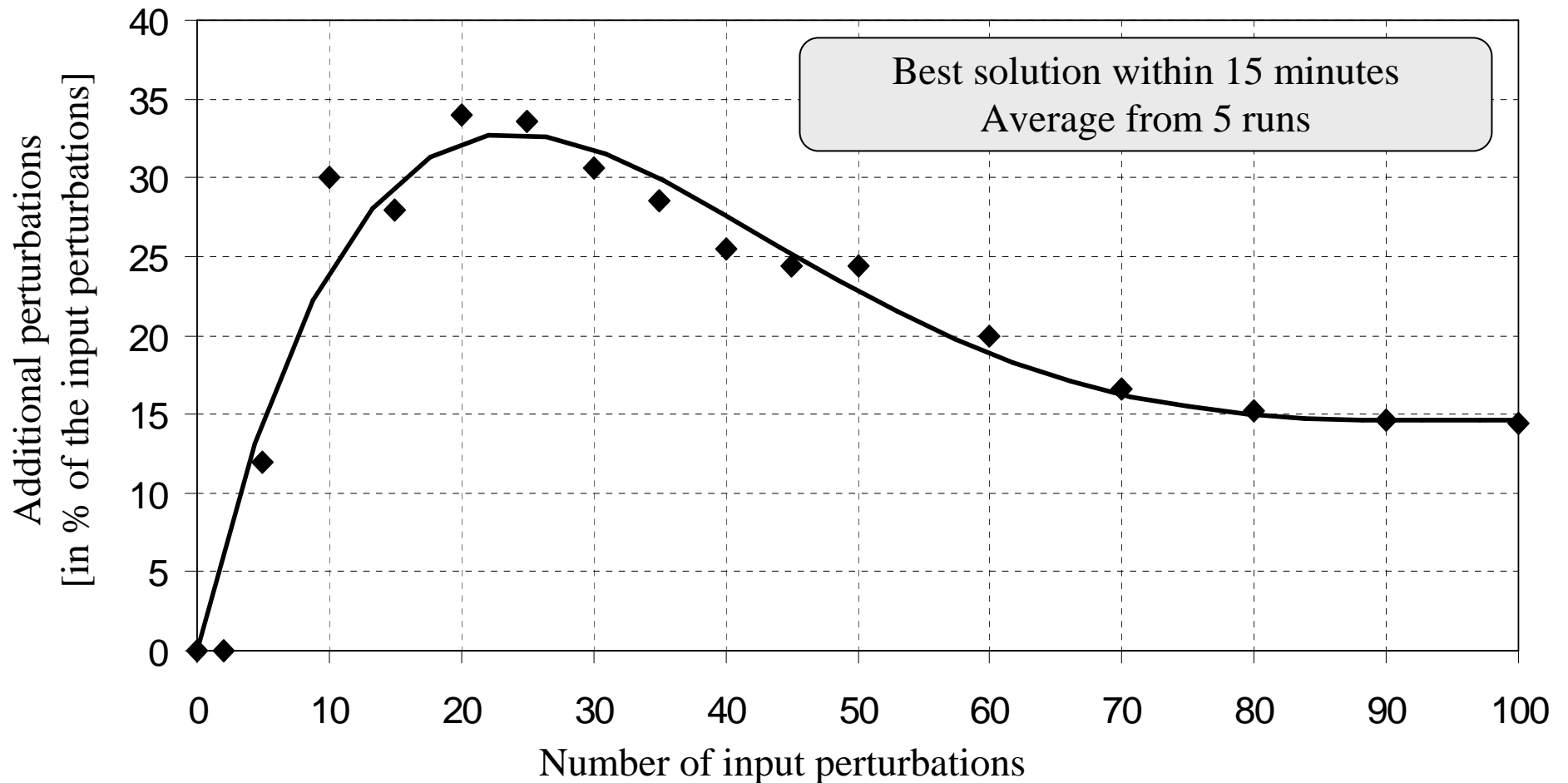
Results from Fall 2001
are presented in the paper

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

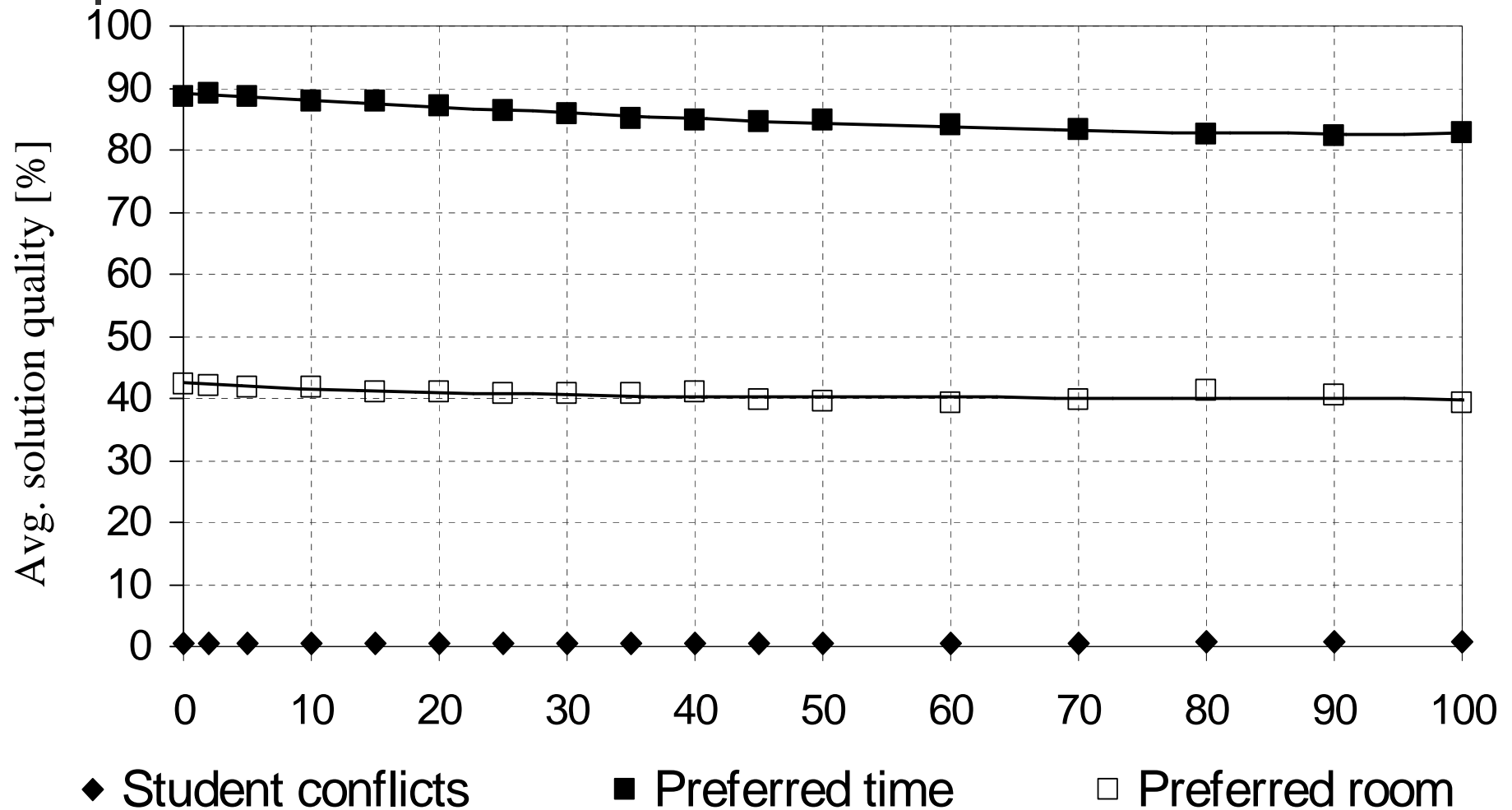
Still at least 5
unassigned
classes after 3
hours

Experiments:

Minimal Perturbation Problem

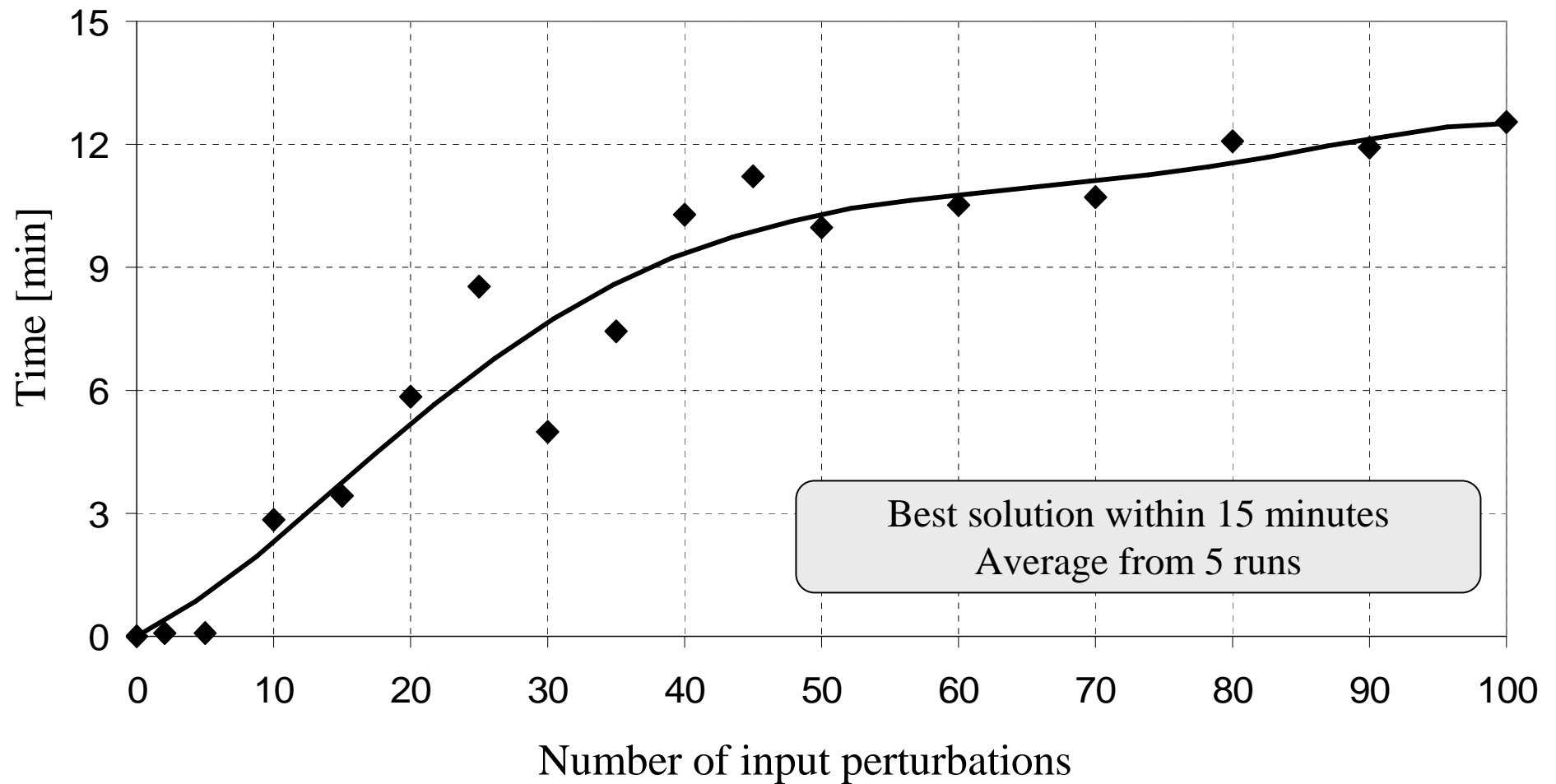


Experiments: Minimal Perturbation Problem



Experiments:

Minimal Perturbation Problem



- 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	7:30a	8:30a	9:30a	10:30a	11:30a	12:30a	1:30p	2:30p	3:30p
EE 270									
Mon		MSE230 1001 0, 2, 0	ECET209 1001 0, 1, 0	AUSL227 1001 2	CSR331 1001	MSE230 2001 0, 2, 0	HIST104 4001 2	ECE321 1001 0, 2, 0	PHPR202 1001 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, 2, 0	ECET209 1001 0, 1, 0	AUSL227 1001 2	CSR331 1001	MSE230 2001 0, 2, 0	HIST104 4001 2	ECE321 1001 0, 2, 0	PHPR202 1001 0, 0, 0
Thu	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
Fri	ECET214 1001 0, 0, 0		ECET209 1001 0, 1, 0	AUSL227 1001 2	CSR331 1001		HIST104 4001 2	ECE321 1001 0, 2, 0	PHPR202 1001 0, 0, 0
EE 170									
Mon	NUCL273 1001 0, 0, 0	NUCL200 1001 0, 8, 0	HTM181 1001 0, 0, 0	IE230 1001 1	C S352 1001 0, 0, 0	MA151 3001 0, 0, 0	ECE270 1001 0, 0, 0	PSY200 2001	NUCL200 1001 0, 0, 0
Tue		EDPS235 1001	PHIL206 1001 2 2	EAS221 1001 5		HIST103 4001 1	F&N202 1001 1		ECE694A 1001 0, 0, 0
Wed	NUCL273 1001 0, 0, 0	NUCL200 1001 0, 8, 0	HTM181 1001 0, 0, 0	IE230 1001 1	C S352 1001 0, 0, 0	MA151 3001 0, 0, 0	ECE270 1001 0, 0, 0	PSY200 2001	ECET196 1001 0, 0, 0
Thu		EDPS235 1001	PHIL206 1001 2 2	EAS221 1001 5		HIST103 4001 1	F&N202 1001 1		ECE694A 1001 0, 0, 0
Fri	NUCL273 1001 0, 0, 0	NUCL200 1001 0, 8, 0	HTM181 1001 0, 0, 0	IE230 1001 1	C S352 1001 0, 0, 0	MA151 3001 0, 0, 0	ECE270 1001 0, 0, 0	PSY200 2001	ECET196 1001 0, 0, 0
EE 129									
Mon	CSR342 1001 10, 4, 0	MA161 1001 0, 0, 0	ENGR100 1001 0, 0, 0	PSY120 4001	MA161 2001 0, 0, 0	MA162 1001 0, 0, 0	PHIL330 1001 2	AGRY320 1001 5, 2, 2	MA162 2001 0, 1, 0
Tue	AGEC217 3001 0, 0, 0		ENGR100 2001 0, 0, 0	HIST152 2001 1	ECON251 3001 0, 0, 0		PSY120 1001 1 2		PSY120 5001 3, 1, 1
Wed	CSR342 1001 10, 4, 0	MA161 1001 0, 0, 0	ENGR100 3001 0, 1, 0	PSY120 4001	MA161 2001 0, 0, 0	MA162 1001 0, 0, 0	PHIL330 1001 2	AGRY320 1001 5, 2, 2	MA162 2001 0, 1, 0



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