Interactive Course Timetabling

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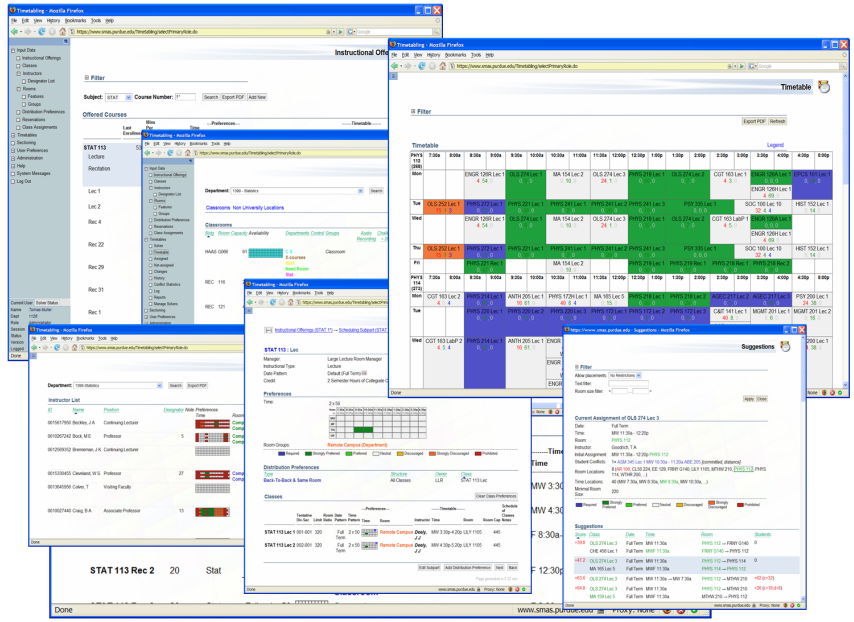


University Timetabling System http://www.unitime.org

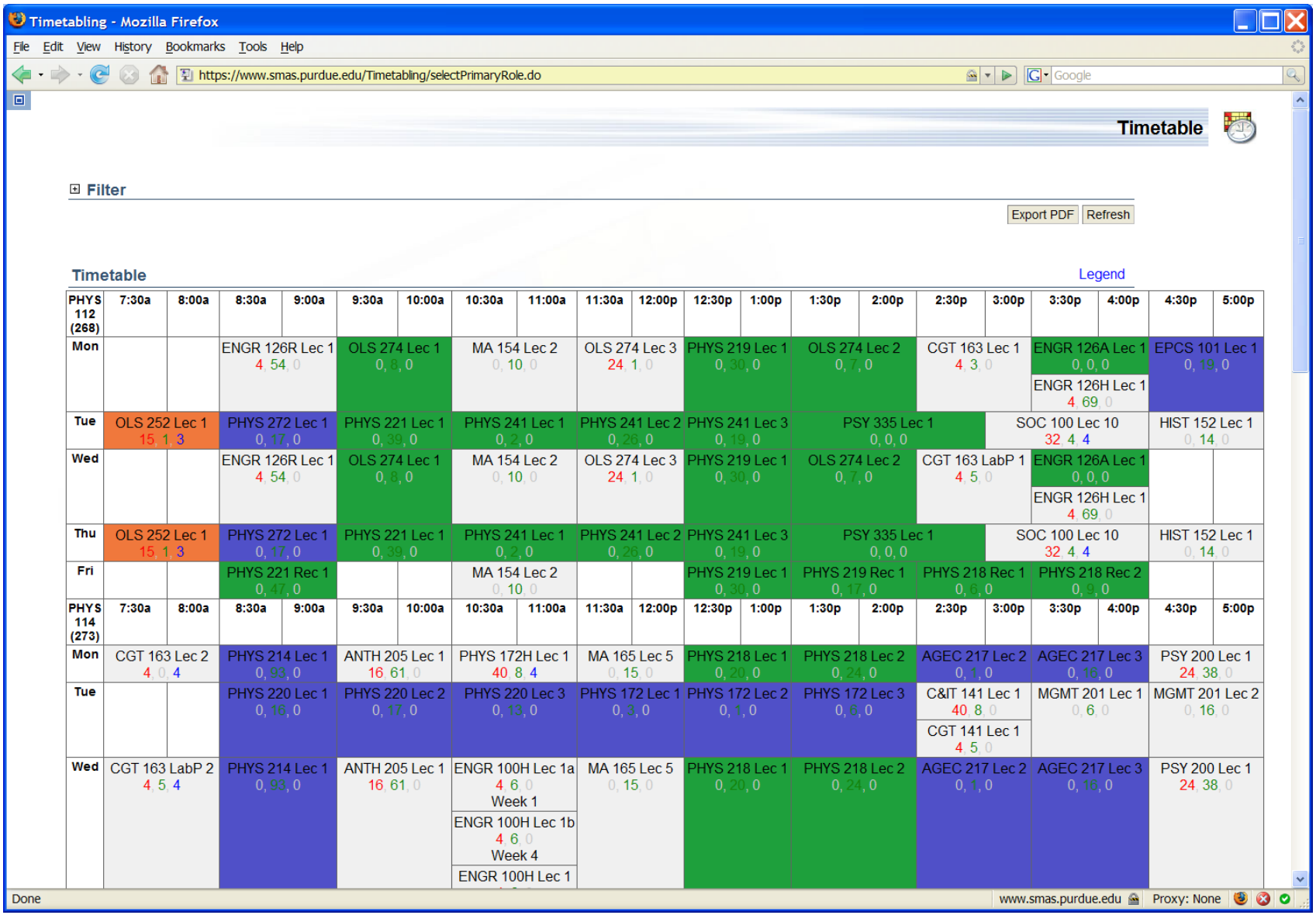
Comprehensive university timetabling system

- used for generation of timetables at Purdue University (USA)
- course timetabling
- exam timetabling
- event scheduling
- student scheduling under development

Course timetabling

- decentralized problem solving
- about 70 problems of different characteristics and complexity
  - about 40.000 students
  - about 7.700 classes per term in total
  - about 1.000 classes in the largest problem
- automated computing of timetables
- interactive changes of generated timetables

Interactive Changes of Course Timetable



PHYS 112 (268)	7:30a	8:00a	8:30a	9:00a	9:30a	10:00a	10:30a	11:00a	11:30a	12:00p	12:30p	1:00p	1:30p	2:00p	2:30p	3:00p	3:30p	4:00p	4:30p	5:00p
Mon			ENGR 126R Lec 1 4, 54, 0		OLS 274 Lec 1 0, 8, 0		MA 154 Lec 2 0, 10, 0		OLS 274 Lec 3 24, 1, 0		PHYS 219 Lec 1 0, 30, 0		OLS 274 Lec 2 0, 7, 0		CGT 163 Lec 1 4, 3, 0		ENGR 126A Lec 1 0, 0, 0 ENGR 126H Lec 1 4, 69, 0		EPCS 101 Lec 1 0, 19, 0	
Tue	OLS 252 Lec 1 15, 1, 3		PHYS 272 Lec 1 0, 17, 0		PHYS 221 Lec 1 0, 39, 0		PHYS 241 Lec 1 0, 2, 0		PHYS 241 Lec 2 0, 26, 0		PHYS 241 Lec 3 0, 19, 0		PSY 335 Lec 1 0, 0, 0			SOC 100 Lec 10 32, 4, 4			HIST 152 Lec 1 0, 14, 0	
Wed			ENGR 126R Lec 1 4, 54, 0		OLS 274 Lec 1 0, 8, 0		MA 154 Lec 2 0, 10, 0		OLS 274 Lec 3 24, 1, 0		PHYS 219 Lec 1 0, 30, 0		OLS 274 Lec 2 0, 7, 0		CGT 163 LabP 1 4, 5, 0		ENGR 126A Lec 1 0, 0, 0 ENGR 126H Lec 1 4, 69, 0			
Thu	OLS 252 Lec 1 15, 1, 3		PHYS 272 Lec 1 0, 17, 0		PHYS 221 Lec 1 0, 39, 0		PHYS 241 Lec 1 0, 2, 0		PHYS 241 Lec 2 0, 26, 0		PHYS 241 Lec 3 0, 19, 0		PSY 335 Lec 1 0, 0, 0			SOC 100 Lec 10 32, 4, 4			HIST 152 Lec 1 0, 14, 0	
Fri			PHYS 221 Rec 1 0, 47, 0				MA 154 Lec 2 0, 10, 0				PHYS 219 Lec 1 0, 30, 0		PHYS 219 Rec 1 0, 17, 0		PHYS 218 Rec 1 0, 6, 0		PHYS 218 Rec 2 0, 9, 0			
PHYS 114 (273)	7:30a	8:00a	8:30a	9:00a	9:30a	10:00a	10:30a	11:00a	11:30a	12:00p	12:30p	1:00p	1:30p	2:00p	2:30p	3:00p	3:30p	4:00p	4:30p	5:00p
Mon	CGT 163 Lec 2 4, 0, 4		PHYS 214 Lec 1 0, 93, 0		ANTH 205 Lec 1 16, 61, 0		PHYS 172H Lec 1 40, 8, 4		MA 165 Lec 5 0, 15, 0		PHYS 218 Lec 1 0, 20, 0		PHYS 218 Lec 2 0, 24, 0		AGEC 217 Lec 2 0, 1, 0		AGEC 217 Lec 3 0, 16, 0		PSY 200 Lec 1 24, 38, 0	
Tue			PHYS 220 Lec 1 0, 16, 0		PHYS 220 Lec 2 0, 17, 0		PHYS 220 Lec 3 0, 13, 0		PHYS 172 Lec 1 0, 3, 0		PHYS 172 Lec 2 0, 1, 0		PHYS 172 Lec 3 0, 6, 0		C&IT 141 Lec 1 40, 8, 0 CGT 141 Lec 1 4, 5, 0		MGMT 201 Lec 1 0, 6, 0		MGMT 201 Lec 2 0, 16, 0	
Wed	CGT 163 LabP 2 4, 5, 4		PHYS 214 Lec 1 0, 93, 0		ANTH 205 Lec 1 16, 61, 0		ENGR 100H Lec 1a 4, 6, 0 Week 1 ENGR 100H Lec 1b 4, 6, 0 Week 4 ENGR 100H Lec 1		MA 165 Lec 5 0, 15, 0		PHYS 218 Lec 1 0, 20, 0		PHYS 218 Lec 2 0, 24, 0		AGEC 217 Lec 2 0, 1, 0		AGEC 217 Lec 3 0, 16, 0		PSY 200 Lec 1 24, 38, 0	

Suggestions

Changes with class "POL 101 Lec 3" are considered

Suggestions

Score	Class	Date	Time	Room	Students
+15.2	POL 101 Lec 3	Full Term	TTh 12:00p → TTh 7:30a	BRNG 2280	+11
+31.7	POL 101 Lec 3	Full Term	TTh 12:00p → TTh 10:30a	BRNG 2280	+36 (h+3)
	HIST 342 Lec 1	Full Term	TTh 10:30a → TTh 1:30p	BRNG 2280 → BRNG 2290	
+36.6	POL 101 Lec 3	Full Term	TTh 12:00p → TTh 10:30a	BRNG 2280	+36 (h+4)
	HIST 342 Lec 1	Full Term	TTh 10:30a → TTh 7:30a	BRNG 2280	
+44.1	POL 101 Lec 3	Full Term	TTh 12:00p → TTh 10:30a	BRNG 2280	+34 (h+2)
	HIST 342 Lec 1	Full Term	TTh 10:30a → TTh 3:00p	BRNG 2280 → BRNG 2290	
	OBHR 330 Lec 4	Full Term	TTh 3:00p	BRNG 2290 → LWSN B155	

(all 1571 possibilities up to 3 changes were considered, top 4 of 17 suggestions displayed)

Search Deeper

Interaction Process: Variables

Timetabling problem P: weighted constraint satisfaction problem

- hard constraints must be satisfied
- soft constraints are satisfied to a certain degree/weight
- objective function F summerizes weights of soft constraints

Initial solution δ

initial timetable of the interaction process

Interaction Process: Variables

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- objective function F summerizes weights of soft constraints

Initial solution δ

initial timetable of the interaction process

Selected assignments μ: changes made with the timetable δ

during current interaction

Selected class v

to modify its placement or to be placed into the timetable

Interaction Process: Variables

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- hard constraints must be satisfied
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- objective function F summerizes weights of soft constraints

Initial solution δ
: initial timetable of the interaction process

Selected assignments μ: changes made with the timetable δ
: during current interaction

Selected class v
: to modify its placement or to be placed into the timetable

Suggestions Ω: set of generated assignments ω
: making the timetable feasible (all hard constraints are satisfied)

Conflicting assignments γ
: set of assignments conflicting with selected assignments μ

Simplified Interaction Process

procedure INTERACTION(P, δ, v)

$\mu = \emptyset$

$A = \{v \neq d_v\}$

while true do

$\Omega \quad = \text{BB}(P \cup A, \delta, \mu, v)$

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while true do

$\Omega \quad = \text{BB}(P \cup A, \delta, \mu, v)$

$S = \text{COMMUNICATION}(\Omega)$

Simplified Interaction Process

procedure INTERACTION(P, δ, v)
  $\mu = \emptyset$
  $A = \{v \neq d_v\}$
  while true do
    Ω = BB($P \cup A, \delta, \mu, v$)
    S = COMMUNICATION(Ω)

    case (S) *commit*($\omega \in \Omega$): δ = join($\delta, \mu \cup \omega$); **return**
      abort: **return**
      selectAssignment(d_n): $\mu = \mu \cup \{v/d_n\}$
      selectFilter(α): $A = \alpha v$

    end case
  end while
end procedure

Simplified Interaction Process

procedure INTERACTION(P, δ, v)
  $\mu = \emptyset$
  $A = \{v \neq d_v\}$
  while true do
    $(\Omega, \gamma) = \text{BB}(P \cup A, \delta, \mu, v)$
    $S = \text{COMMUNICATION}(\Omega, \gamma)$

    case (S) *commit*($\omega \in \Omega$): $\delta = \text{join}(\delta, \mu \cup \omega)$; **return**
      abort: **return**
      selectAssignment(d_n): $\mu = \mu \cup \{v/d_n\}$
      selectFilter(α): $A = \alpha v$
      selectClass($c \in \{\mu \cup \gamma \cup \Omega\}$): $v = c$; $A = \{v \neq d_v\}$
      removeClass($c \in \mu$): $\mu = \mu \backslash \{c/d_c\}$
    end case
  end while
end procedure

Branch and Bound (BB) $\Omega = \mathrm{BB}(P \cup A, \delta, \mu, v)$

Variables

- weighted constraint satisfaction problem P
- filter A
- initial timetable δ
- selected assignments μ
- class to be (re-)placed v

Initialization

- compute conflicting assignment caused by μ

Run BB to find assignments of variables for

- class v
- classes involved in conflicting assignments

Branch and Bound (continues)

Run BB

- n best suggestions ω are given to user
- search with timeout
- best values (based on contribution to F) explored first

Bounds

- limited search depth
  - to allow changes of small number of variables only
  - to include changes of one new class it does make sense to change too many other classes
- F must be better than the n-th best found suggestion

Branch and Bound (continues)

Run BB

- n best suggestions ω are given to user
- search with timeout
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Bounds

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Repeat BB: process another run of BB with

- increased search depth or
- increased timeout

Experiments

Problem	pu-fal07-llr		pu-spr07-llr	
Classes	891		803	
Time limit (s)	–	5	–	5
Time spent (s)	128.6	4.7	39.9	4.2
Number of backtracks	66367.9	2886.9	13949.1	2592
Optimal suggestion found (%)	98.4	51.5	99.2	67.0
Improvements in objective function (%)	+1.1	+0.8	+0.9	+0.7

Demonstration

See `http://www.unitime.org/uct_demo.php` for online demo