Optimization project

Course scheduling in the Computer Science and Optimization Department of Monfort College

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Problem description

Diverse Faculty with different qualifications, availability and workload

Varied Curriculum composed of courses with different class loads and caveats

Balancing Preferences maximizing faculty and student body choices

Problem formalization

Course assignment stage

- Courses (C): {CS01, CS02, CS03, CS04, CS05, CS06, CS07, CS08}
- Faculty members (F): {Barbosa, Castro, Gerardo, Lameiras, Machado, Pedro, Queirós, Soeiro, contingent MWF, contingent TuTh}

Parameters

S_f: Seniority of faculty f
L_f: Course load for faculty f

N_c: Required classes for course c

$P_{f,c}$: Preference of faculty f for course c
$Q_{f,c}$: Qualification of faculty f for course c

X: Weight for soft restriction 5
W_1: Weight for soft restriction 6
W_2: Weight for soft restriction 7

Decision Variables

$r_{f,c}$: Number of classes of course c given by faculty f
$b_{f,c}$: Boolean variable ($r_{f,c} \geq 1$)

u_f: Used for soft restriction 6
v_f: Used for soft restriction 7

Objective function

Maximize

$$\sum_f \sum_c r_{f,c} P_{f,c} S_f - W_1 \sum_f u_f - W_2 \sum_f v_f$$

Problem formalization

Scheduling stage

- Time slot IDs: {1, 2, 3, 4, 5, 6, 7}
- MWF/TuTh time slots: {9:10, 10:20, ...} / {8:15, 9:50, ...}

Parameters

S_f: Seniority of faculty member f

$R_{f,c}$: Number of classes of course c given by faculty member f

$P_{f,t}$: Preference of faculty f for time slot t

T_t: Start time of time slot t
Δ: Duration of the time slots

W_3, W_4, W_5: Weights for soft restrictions 11, 12 and 13

Decision Variables

$a_{f,c,t}$: pairing of a course-faculty pair (f, c) to a time slot t.

$y_{f,t}$: Used for soft restriction 12

$z_{f,t}$: Used for soft restriction 13

Objective function

Maximize

$$\sum_f \sum_c \sum_t a_{f,c,t} P_{f,t} S_f - W_3 U - W_4 \sum_f \sum_t y_{f,t} - W_5 \sum_f \sum_t z_{f,t}$$

Problem formalization

Course assignment stage - Constraints

Domain constraints

$r_{f,c} \in \mathbb{Z}_0^+$ $\quad u_f \in \mathbb{Z}_0^+$

$b_{f,c} \in \{0,1\}$ $\quad v_f \in \mathbb{Z}_0^+$

1. **Each faculty is assigned to only the courses that he/she is qualified to teach**
   $\forall f, c : r_{f,c}(1 - Q_{f,c}) = 0$
2. **Each full-time faculty member's actual course load must be equal to his/her required course load per semester according to their contracts**
   $\forall f \neq \alpha : \sum_c r_{f,c} = L_f$
3. **The number of classes assigned to faculties needs to be equal to the number of classes required by each course**
   $\forall c : \sum_f r_{f,c} = N_c$
4. **Relate $r_{f,c}$ to boolean counterpart $b_{f,c}$**
   $\forall f \neq \alpha, c : r_{f,c} \leq b_{f,c} \cdot L_f$
   $\forall c : r_{\alpha,c} \leq b_{\alpha,c} \cdot M$
   $\forall f, c : r_{f,c} \geq b_{f,c}$
5. **All courses, and particularly CSO6, are to be taught by full-time faculty, if possible**
   $$P_{\alpha,c} = P_{\beta,c} = \begin{cases} -1, & \text{if } c \neq 6 \\ -X, & \text{otherwise} \end{cases}$$
6. **Ideally, the number of preparations (different courses that each faculty taught per semester) for each full-time faculty would be no more than two**
   $\forall f \neq \alpha : \sum_c b_{f,c} \leq 2 + u_f$
7. **Ideally, no more than two classes of the course CSO3 should be assigned to any full-time faculty**
   $\forall f \neq \alpha : r_{f,3} \leq 2 + v_f$

Problem formalization

Scheduling stage - Constraints

Domain constraints

$a_{f,c,t} \in \{0,1\}$

$y_{f,t} \in \{0,1\}$

$z_{f,t} \in \{0,1\}$

8. **Each full-time faculty member can be teaching at most one course on a given time slot**

$$\forall f \neq \alpha, t : \sum_{c} a_{f,c,t} \leq 1$$

9. **A teacher must lecture exactly as many time slots of a course as he was assigned in a previous stage**

$$\forall f, c : \sum_{t} a_{f,c,t} = R_{f,c}$$

10. **At most three course classes can be assigned to the same class period**

$$\forall t : \sum_{f} \sum_{c} a_{f,c,t} \leq 3$$

11. **Most of the students and faculty prefer that their class day begins after 9:00 AM and ends before 4:00 PM**

$$U = \sum_{f} \sum_{c} \sum_{\substack{t: T_t < 9{:}00 \vee \\ T_t + \Delta > 16{:}00}} a_{f,c,t}$$

12. **Avoid having instructors teach more than two consecutive class periods**

$$\forall f, \forall t \leq |T| - 2 :$$
$$\sum_{c} (a_{f,c,t} + a_{f,c,t+1} + a_{f,c,t+2}) \leq 2 + y_{f,t}$$

13. **Avoid having instructors teach back-to-back classes in the afternoon**

$$\forall f, \forall t \leq |T| - 1 \wedge T_t \geq 12{:}00 :$$
$$\sum_{c} (a_{f,c,t} + a_{f,c,t+1}) \leq 1 + z_{f,t}$$

Results

Course assignment stage

Course	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Barbosa	1		2						3
Castro				1		1			2
Gerardo						2		1	3
Lameiras	1	2							3
Machado			1						1
Pedro		1	2						3
Queirós		3							3
Soeiro						3			3
Contingent					1		1		2
Total	2	6	5	1	1	6	1	1	23

$$W_1 = 1; W_2 = 4; X = 2$$

Results

Scheduling stage

Day	MWF
09:10	α7
10:20	B3, P3, Q2
11:30	P2, Q2
13:30	B3, P3, Q2
14:40	B1, α5
15:50	C6
17:25	C4

Day	Tu/Th
08:15	M3
09:50	G6, L2, S6
11:25	G6, L2, S6
13:00	L1
14:35	G8, S6
16:10	
18:00	

$$W_3 = 10; W_4 = 1; W_5 = 1$$

Discussion

How to handle seniority

Initially, we were using $r_{f,c}(A \cdot P_{f,c} + B \cdot S_f)$ and $a_{f,c,t}(C \cdot P_{f,d,t} + D \cdot S_f)$.

Adding proved not to be the best solution.

Multiply preferences of faculties by their seniority, so seniors' choices are more important than juniors' choices.

Discussion

Hard and soft constraints

Hard constraints are enforced

Soft constraints are incorporated as penalties on the objective function:

1. Quantify how much a soft constraint is being violated
2. Multiply that by a weight
3. Subtract that from the objective function

Discussion

Alternative solution

Join the two stages:

- Use all parameters and decision variables
- Trivially combine the objective functions