Course Scheduling Considering Faculty and Student Time Preferences

Darshan R. Chauhan

10th February, 2022

Problem Description and Formulation

The motivation of formulating the course scheduling problem is to ease the effort on manual course scheduling and faculty assignment performed every quarter by the Civil and Environmental Engineering Department staff at the Portland State University. The intention of this work is to schedule the courses held multiple times each week, which would act as a base for arriving at the finalized schedule.

The optimization program requires traditional trivial information like time-slots, course offerings, list of faculty members and their compatibility with a given course, and student group/batch information, as well as some new type of information which might not have been explicitly considered while previous scheduling like expected course participation, time preferences of student groups and faculty, and faculty requiring all their assigned courses to be in the same weekly cycle (all on Monday-Wednesday or all on Tuesday-Thursday). The objective of the program is to maximize the weighted sum of faculty and student time preference achieved from scheduling.

The developed code and test examples are available at: https://github.com/drc1807/CSP

Nomenclature

Sets and Indices

$\mathcal{T}$	Set of all time slots, indexed as $t, t' \in \mathcal{T}$. This represent the scheduling non-repeating time slots for the courses, like M 8-9:50am (and, W 8-9:50am is implied to be automatically scheduled with the same course), M 10-11:50am, and so on.
$\mathcal{D}$	Set of different days represented in the set $\mathcal{T}$, indexed as $d \in \mathcal{D}$.
$\mathcal{I}$	Set of all course offerings for the scheduling term of interest, indexed as $i, i' \in \mathcal{I}$.
$\mathcal{J}$	Set of all faculty members available to teach an offered course in the scheduling term of interest, indexed as $j \in \mathcal{J}$.
$\mathcal{J}'$	Set of faculty members that need to assigned to all their courses on the same day (i.e., MW cycle or TR cycle), indexed by $j \in \mathcal{J}'$
$\mathcal{K}$	Set of all student group/batch attending classes in the scheduling term of interest, indexed as $k \in \mathcal{K}$. Some potential set members of set $\mathcal{K}$ could be Freshmen, Sophomore, Junior Track 1, Junior Track 2, Senior Track 1, Senior Track 2, and speciality-wise graduate students. However, we can adopt as detailed a description was we want (all the way to the individual student level) depending on the data availability.

Decision Variables

x_{it}	1, if course $i \in \mathcal{I}$ is assigned to time slot $t \in \mathcal{T}$, and 0, otherwise.
y_{jit}	1, if faculty member $j \in \mathcal{J}$ teaches course $i \in \mathcal{I}$ offered during time slot $t \in \mathcal{T}$, and 0, otherwise.

Parameters or Input Data

a_{it}	1, if course $i \in \mathcal{I}$ can be offered during time slot $t \in \mathcal{T}$, and 0, otherwise.
cf_{ij}	1, if course $i \in \mathcal{I}$ can be taught by faculty member $j \in \mathcal{J}$, and 0, otherwise.
m_j	maximum number of courses that can be assigned to faculty member $j \in \mathcal{J}$.
$cc_{ii'}$	1, if course $i \in \mathcal{I}$ and course $i' \in \mathcal{I}, i' \neq i$ cannot be taught together, and 0, otherwise.
$ct_{tt'}$	1, if time slots $t \in \mathcal{T}$ and time slot $t' \in \mathcal{T}$ are overlapping, and 0, otherwise.
s_k	total number of students in student group $k \in \mathcal{K}$.
ep_{ki}	Expected participation of student group $k \in \mathcal{K}$ in course $i \in I$; $ep_{ki} \leq s_k$ (Note, we can also modify this to b_{ikt} to include the time slot component).
TD_{td}	a 1, if time slot $t \in \mathcal{T}$ is part of day $d \in \mathcal{D}$, and ∞, otherwise.
p^S_{kt}	Preference rating of student group $k \in \mathcal{K}$ to attend a course during time slot $t \in \mathcal{T}$ (higher value implies more preferable).
p^F_{jt}	Preference rating of faculty member $j \in \mathcal{J}$ to teach a course during time slot $t \in \mathcal{T}$ (higher value implies more preferable).
α^S	importance given to student time preference; $\alpha^S \geq 0$.
α^F	importance given to faculty time preference; $\alpha^F \geq 0$.

Model Formulation

For the model, our objective is maximizing weighted time preference of students and faculty, as shown in equation (1).

$$\max_{x,y} \quad \alpha^S \sum_{k\in\mathcal{K}} \sum_{i\in\mathcal{I}} \sum_{t\in\mathcal{T}} \frac{p^S_{kt} ep_{ki}}{s_k} x_{it} + \alpha^F \sum_{j\in\mathcal{J}} \sum_{i\in\mathcal{I}} \sum_{t\in\mathcal{T}} p^F_{jt} y_{jit} \tag{1}$$

Note that in the above objective function, we can remove student preference by setting $\alpha^S = 0$, and we can remove faculty preference by setting $\alpha^F = 0$.

Equation (2) ensures that all the offered courses are a part of final schedule and are offered a time slot. Equation (3) enforces that all courses are assigned a faculty member to each it.

$$\sum_{t\in\mathcal{T}} x_{it} = 1 \quad \forall\, i \in \mathcal{I} \tag{2}$$

$$\sum_{j\in\mathcal{J}} \sum_{t\in\mathcal{T}} y_{jit} = 1 \quad \forall\, i \in \mathcal{I} \tag{3}$$

Next, equation (4) ensures that a course is offered in compatible time slots. Using equation (5), we ensure that two non-time-compatible courses are not offered during the same time slot or overlapping time slot.

$$x_{it} \leq a_{it} \quad \forall\, i \in \mathcal{I}, t \in \mathcal{T} \tag{4}$$

$$x_{it} + c_{tt'} c_{ii'} x_{i't'} \leq 1 \quad \forall\, i, i' \in \mathcal{I},\ t, t' \in \mathcal{T} \tag{5}$$

Equations (6) and (7) ensure that a faculty member is assigned to the course during the same time slot it is offered, and that the faculty member can teach the offered course, respectively.

$$y_{jit} \leq x_{it} \quad \forall\, j \in \mathcal{J}, i \in \mathcal{I}, t \in \mathcal{T} \tag{6}$$

$$y_{jit} \leq cf_{ij} \quad \forall\, j \in \mathcal{J}, i \in \mathcal{I}, t \in \mathcal{T} \tag{7}$$

Equations (8) and (9) enforce that a faculty member is only assigned one course during a time slot and that the maximum course load that is assigned to a faculty member $j \in \mathcal{J}$ is limited by m_j, respectively.

$$\sum_{i \in \mathcal{I}} y_{jit} \leq 1 \quad \forall\, j \in \mathcal{J}, t \in \mathcal{T} \tag{8}$$

$$\sum_{i \in \mathcal{I}} \sum_{t \in \mathcal{T}} y_{jit} \leq m_j \quad \forall\, j \in \mathcal{J} \tag{9}$$

Equation (10) facilities allocation of all courses to a pre-selected faculty member in one cycle (MW or TR).

$$\sum_{i \in \mathcal{I}} \sum_{t \in \mathcal{T}} TD_{td}\, y_{jit} \leq m_j \quad \forall\, j \in \mathcal{J}', d \in \mathcal{D} \tag{10}$$

Finally, equations (11) and (12) define the domain of decision variables.

$$x_{it} \in \{0, 1\} \quad \forall\, i \in \mathcal{I}, t \in \mathcal{T} \tag{11}$$

$$y_{jit} \in \{0, 1\} \quad \forall\, j \in \mathcal{J}, i \in \mathcal{I}, t \in \mathcal{T} \tag{12}$$

The above optimization problem with objective function (1) and constraints (2)-(12) is defined as the Course Scheduling Problem (CSP) which considers student and faculty time preferences in decision making. CSP is an integer linear program and can be solved using any commercially-available MIP solver.

Acknowledgments

Many thanks to Kiley Melicker, Academic Program Manager at the Civil and Environmental Engineering Department at Portland State University, for providing the insights on the data availability and decision priorities, and walking me through the manual decision-making process.