Exam Scheduling Project

Bayzhan Mukatay, under the mentorship of Professor Illya V. Hicks and his research group

Problem

The current manual process of creating the final exam schedule at Rice University's registrar's office is both time-consuming for staff and problematic for students. Every semester, it takes more than 8 hours to come up with a schedule, which usually has shortcomings that negatively impact the student experience. For example, it can lead to an unfair distribution of exams, where some students have to take multiple exams on the same day, while others have more time to prepare and relax. In other cases, it can cause inconvenience for students who are forced to remain on campus for an extra week only to take one exam. Additionally, scheduling exams in inconvenient classrooms can cause undue stress for both faculty and students, leading to numerous requests for exam time rescheduling and classroom changes.

Every student requesting an exam reschedule can cost instructors around 3 hours of their time. With Rice University's undergraduate population exceeding 4480, these inefficiencies and time losses can become a significant problem. Therefore, it is critical that Rice University adopts a more efficient and student-friendly approach to creating the final exam schedule. By doing so, the university can improve the overall student experience while saving valuable time and resources for both students and faculty.

This project proposes a schedule generation algorithm that uses mixed integer programming techniques to find an optimal, or near-optimal solution.

Background information

The university administration sets the following **hard constraints:**

1. Each exam must be scheduled for a specific classroom-time combination, referred to as a "slot”. Each classroom is available thrice a day (morning, noon, evening) during 7 days period.
2. Take-home exams are matched with a specific day;
3. Online exams are matched with a specific time;

4. Classrooms must be at least twice the size of the exam group (splitting a classroom into multiple sections is allowed when necessary);
5. Exams for different sections of the same class take place simultaneously;
6. Classroom preferences must be accommodated, with ARCH exams scheduled at Anderson Hall, MUSI exams at Shepherd Hall, and BUSI exams at McNeir Hall.

Moreover, the registrar's office aims to achieve the following **objectives** when creating the exam schedule:

1. Minimize the number of students taking more than two exams in two consecutive days.
2. Schedule exams as early as possible.
3. Allow for reasonable time buffers between exams (one day between two exams is ideal)
4. Ideally, match exams to the classroom where the corresponding lectures were held, with lecture classes taking place in lecture rooms and conference classes in conference rooms.

Solution

To address the complex scheduling needs of Rice University's registrar's office, we have developed an algorithm has that leverages two mixed integer programs.

The first program provides a heuristic that identifies which of the classes need to be divided into multiple parts based on the hard constraints of the scheduling process.

The second mixed integer program incorporates the updated exam sections and the objectives of the scheduling process. This includes minimizing the number of students taking more than two exams consecutively, scheduling exams as early as possible, and allowing for reasonable time buffers between exams. Additionally, this program aims to match exams to the classroom where the corresponding lectures were held, with lecture classes taking place in lecture rooms and conference classes in conference rooms.

By utilizing these two programs, the algorithm can efficiently create a final exam schedule that satisfies the hard constraints and achieves the objectives set by the registrar's office.

Part 1

Notation & Data

$\text{S} = \text{set of all uniqe scheudles } \ (\text{e.g.}\{\{\text{CAAM 476, PHIL 370, STAT 311}\}, \{\text{HIST 102, MATH 212}\}...\})$
$\forall T \in S,\ N_T = \#\text{ of students with schedule T}$

$E = \text{set of exams.}$
$\forall e \in E,\ d_e = \#\text{ of students taking exams e.}$
$Let\ E_p,\ E_o \text{ be sets of in person and online exams s.t. } E = E_p \cup E_o.$

$R = \text{set of all slots (classroom-time pairs).}$
$Let\ R_p\ and\ R_o \text{ be in person and "online" partiotions of R respectively.}$
$\forall r \in R_p,\ c_r = \#\text{ of seats in the classroom (capacity)}; \forall r \in R_o,\ c_r = \infty.$

$\text{Online classrooms have unlimited capacities and exist as slots representing online exams.}$
$\text{Let } L_i \text{ be the set of all slots in R on days i and i+1.}$

Also let L_i^t to represent the set of slots on day i and time $t \in \{1, 2, 3\}$

$Q = \text{set of exam sections (e.g } \{\{\text{MATH 101 01, MATH 101 02}\}...\ \})$

Decision Variables

$$\forall r \in R,\ \forall e \in E,\ x_{re} \triangleq \begin{cases} \text{1 if exam e is matched with slot r;} \\ \text{0 otherwise} \end{cases}$$

$$\forall T \in S,\ \forall i \in \{1, ..., 6\},\ y_{Ti} \triangleq \text{ \# extra class in consecutive days i and i+1 for schedule T}$$

$$\forall r \in R_p,\ \forall e \in E_p,\ z_{re} \triangleq \begin{cases} 2d_e - c_r \text{ if } x_{re} = 1 \text{ (capacity violation measure)} \\ 0 \ \text{ otherwise} \end{cases}$$

Objective

$$min \sum_{T \in S} N_T \sum_{i \in \{1...6\}} y_{Ti} \ + \sum_{e \in E_p} \sum_{r \in R_p} z_{re}$$

The first sum minimizes the number of students taking times number of extra classes they take in each consecutive day.

The second sum minimizes the number of matches that violate the capacity constraint. This will be used to find which exams to split in part 2.

Subject to

$$\forall r \in R_P,\ \forall e \in E_p,\ s.t.\ c_r \leq d_e,\ \ x_{re} = 0 \ \text{ (capacity constraint)}$$

$$\forall r \in R_p,\ \forall e \in E_p,\ \ z_{re} \geq (2d_e - c_r) \times x_{re} \ \text{ (capacity violation)}$$

$$\forall e \in E_p, \forall r \in R_o,\ \ x_{re} = 0 \text{ (in-person exams can't have online classrooms)}$$

$$\forall e \in E_o,\ \forall r \in R_p,\ \ x_{re} = 0 \text{ (online exams can't have an in-person classroom)}$$

$$\forall e \in E_p,\ \sum_{r \in R_p} x_{re} = 1 \ \text{ (one in-person slot per each in-person exam)}$$

$$\forall e \in E_o,\ \sum_{r \in R_o} x_{re} = 1 \ \text{ (one "onilne" slot per each "online" exam)}$$

$$\forall r \in R_p,\ \sum_{e \in E_p} x_{re} \leq 1 \ \text{ (at most one in-person exam per in-person slot)}$$

$$\forall i \in \{1...6\},\ \forall T \in S,\ \ y_{Ti} \geq \sum_{r \in L_i} \sum_{e \in T} x_{re} - 2 \ \text{ (exam \# in consecutive days violation)}$$

$$\forall V \in Q,\ \forall t \in \{1, 2, 3\},\ \forall i \in \{1...7\},\ \sum_{r \in L_i^t} \sum_{e \in V} x_{re} = |V| \times \sum_{r \in R_i^t} x_{re_1},\ where\ e_1 \in V$$
$$\text{(sections scheduled at the same time)}$$

$$x_{re} = 1/0 \ \text{ (for specific cases \& room preferences)}$$

$$\begin{gathered} \forall e \in E,\ \forall r \in R,\ x_{re} \in \{0, 1\} \\ \forall e \in E_p,\ \forall r \in R_p,\ z_{re} \geq 0 \\ \forall T \in S,\ \forall i \in \{1...6\},\ \ y_{Ti} \geq 0 \end{gathered}$$

We get that z is nonzero for the following exams:

	SUBJ_CODE	ENRL	EXAM_TYPE
237	CHEM_211_S01	199	Scheduled Final Exam-OTR Room
125	BIOS_201_S01	183	Scheduled Final Exam-OTR Room
848	PHYS_125_S01	166	Scheduled Final Exam-OTR Room
914	PSYC_101_002	158	Scheduled Final Exam-OTR Room
938	PSYC_101_003	158	Scheduled Final Exam-OTR Room
867	PHYS_101_S02	149	Scheduled Final Exam-OTR Room
150	BIOS_301_S01	131	Scheduled Final Exam-OTR Room

We split each exam in two parts, add to Q and solve. Repeat Part 1 until all z's are zero.

Part 2

Let W represent a set of tuples (r, e) representing weights for classroom preferences. This incorporates giving more preference to faculty choice rooms, rooms used during the semester, and slots that are earlier in the exam period.

Same model but with preferences $w_{re} \in W$.

To warm start, we need to rewrite the S and x_{re} in the objective to not include the deleted exams and include new sections

New Objective

$$min \sum_{T \in S} N_T \sum_{i \in \{1...6\}} y_{Ti} + \sum_{(r,e) \in W} w_{re} * x_{re}$$

New Constraints

$$\forall r \in R_P,\ \forall e \in E_p,\ s.t.\ c_r \leq 2 * d_e,\ \ x_{re} = 0 \ \ \text{(capacity constraint)}$$

$$\forall V \in Q,\ \forall t \in \{1, 2, 3\},\ \forall i \in \{1...7\},\ \sum_{r \in R_i^t} \sum_{e \in V} x_{re} = |V| \times \sum_{r \in R_i^t} x_{re_1},\ where\ e_1 \in V$$
$$\text{(new sections scheduled at the same time)}$$

Results

The algorithm reduces the manual scheduling time from 8 hours to 8 minutes and and provides a solution that decreases conflicts (# students taking 3 or more exams in two consecutive days) by 90%, while meeting all university requirements and staff preferences.