# The University Course Selection Problem: Efficient Models and Experimental Analysis *

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**Abstract**

The *university course selection problem* (UCSP) deals with finding an optimal choice of courses from a set of alternatives to attain a prescribed goal. It is assumed that a timetable is already given. If the planning is done for a term, the problem is simple and can be solved by complete enumeration using a computer. For multi-year planning, complete enumeration is impractical. The problem is made more complicated when inter-campus travel is also involved.

In this paper, we formulate UCSP as a maximum weight independent set problem with specially structured additional constraints. Data for the experiments are collected from the SFU student information system. Experimental results using a general purpose integer programming solver are given. Our model could easily solve the problem, producing an optimal solution in very reasonable running time.

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# 1 Introduction

The *university course selection problem* (UCSP) is a combinatorial optimization problem that requires finding a schedule for students to determine which courses and sections will be taken. In recent years, the UCSP has become increasingly difficult because of the flexible system of electives and programs tailored to meet individual needs and preferences. On the other hand, in many universities, on-line course support systems, which allow students to view all course information, are available. However, it is not easy for students to generate a course schedule manually from a large number of combinations of classes, due to various constraints, especially for some courses that have many different sections at different times, or even on different campuses.

The primary objective of this study is to derive an approximate one-term solution to the UCSP for students, with additional inter-campus travel constraints. Related work by Nozawa et al.[13] had proposed a syllabus analysis system. In designing an original curriculum for a higher education institution, or in external evaluation of an institution's curriculum, comprehending the curriculum contents of many institutions in the same field is necessary. However, the main aim of this system is not for students, but for teachers to make specialized curricula, and our goal is to make a model to solve the UCSP with consideration of students' personal preferences. Timetabling problems are often over-constrained, which is the case with our problem since it is not possible to satisfy all requests of students for enrollment in specific courses [5,16]. Soft constraints can be applied to define these requirements declaratively rather than encapsulating many of them into the control part of the problem solution [2,10]. Eugene and Richard [10] have solved this problem by applying a weighted *constraint satisfaction problem*(CSP) approach, which considers weights or costs for each constraint and minimizes the weighted sum of unsatisfied constraints [1]. University course scheduling is a well-studied area with a large amount of literature. However, most systems are used for educational institutions, and those algorithms have not been improved to take into consideration the concerns of inter-campus travel.

# 2 The Problem

We aim to develop an integer optimization model to help university students, especially for universities with multiple campuses, to solve their course selection problem. Firstly, our system is based on a user database. The database is a repository of student data. From this database, the system can extract a user profile, which contains all the information needed for UCSP. This information involves a timetable, which contains a set of courses a student wishes to enroll in for the next term, including information for each course, such as the class time, instructor and campus location. The student profile can also capture other information about the student, such as personal preferences.

The most fundamental parts of our model are to make sure that students have no time conflicts, and to minimize the total length of all breaks and transit time in between campuses. Moreover, by introducing personal preference rate of course and course time, minimizing these rates will allow students to obtain a favorable course schedule. In addition, soft constraints are also applied in our model. We will consider costs for each soft constraint, and minimize the weighted sum of unsatisfied constraints. In our model, we utilize soft constraints to penalize an overloaded study day and reward a course-free day.

# 3 Formulation of the Model

## 3.1 Terminology

- Class time unit:

  A Class time unit basically means a one-hour time slot which contains a class. For instance, a 2-hour course is treated as 2 class time units. Class time unit is decision variable in our model.

- A switch:

  When class time unit $i$ and $j$ are both chosen and any class time unit $k$ between $i$ and $j$ is not chosen, we say there is a switch from $i$ to $j$.

- Section: Some courses have several sections. The projective relationship between course and the corresponding sections is one to multiple.

We formulate the UCSP problem as a maximum weight independent set problem with specially structured additional constraints. First of all, each 2-hour class is divided into 2 “class time units”. (Same for the 3-hour class). Once one of the class time units is chosen, the other class time units of the same course must be chosen. In addition, the tutorial is also treated as a class time unit which can be selected if and only if the corresponding course is chosen. Then, each class time unit is represented by a node and the goal is to find an independent set which has no time conflict and in which no two inter-campus classes are adjacent.

Moreover, since SFU has three campuses (Burnaby, Surrey, Downtown), the switches between campuses are counted. The arc between each two intra-campus travel nodes has a cost of 0 while the cost of each two inter-campus travel nodes is 1.

Furthermore, because our model is based on student’s preference, we make the model more sophisticated by adding the reward score system. The system is to ask the user to rate his/her favored time slots and elective courses with a rating from 1 to 10. (where 1 is the best, 10 is the worst). (e.g. A student wants to take classes between 10:30 a.m. and 12:30 a.m., and STAT-445 is an elective course he/she does not like to take. Therefore, if the student can choose this time period, the objective will just add 1, and if the student chooses this course, the objective function will add 10.).

In other words, the principle of this study is to derive an approximate solution to the course scheduling problem for SFU students by minimizing the inter-campus travel time and choosing their favored courses and time periods as many as possible.

## 3.2 Assumptions

- **School time is from 8:30 to 22:30, Monday to Friday.**

  All courses are offered from Monday to Friday. Moreover, the first class starts on 8:30am, and the last class ends at 10:30pm. Students may take such courses, so we need to consider all the possible times.

- **Course times are divided into time slots of 1 hour each.**

  SFU has three different periods of classes run for 1,2 or 3 hours. Therefore, each class can be scheduled in the corresponding time period.

- **The transit times between campuses are fixed.**

  Although the transit time between campuses is fluctuated, it can be treated as a constant cost in the mathematic analysis.

- **The travel time spent between classrooms on campus is neglected**.

  Compared with the travel time between campuses, the intra-campus travel time is very short, since it is only several minutes.

- **Students are able to enroll in all courses considered on the list.**

  We assumed that all the courses on the list are accessible to the student. The student is expected to obtain this list after consulting with the academic advisor. (e.g. Some Economic students cannot choose some popular compulsory courses because of late enrollment date.)

- **Final exam schedule is not considered.**

  If students have three final exams on the same day, they can apply to reschedule the exam time.

## 3.3 Notations, Coefficients, and Variables

Notations:

- $i, j$ :indexes for class time units, $i, j = \{1, 2..., n\}$ and $i < j$.

- $k$: index for class day in a week, $k = \{1, 2, ..., 5\}$.

- $Q$: set of courses, $Q$={$A, B, ...$}.

  $p$: index for compulsory course

  $q$: index for elective course

  $Q_p$: a compulsory course

  $Q_q$: a elective course

- $\alpha$: index for sections, $\alpha = \{A_1, A_2, ..., B_1, B_2, ...\}$.

- $D_k$: the set of class time units from day k.

In order to express the logic relationship of class time units, we want to introduce another index instead of $i, j$ in the selection tree part. For any class time unit $i$, $i = 1, 2, ..., n$, we can notate in the $l$ and $t$ form.

- $l$: index for lecture time unit .

- $t$: index for tutorial time unit.

  Lecture time units and tutorial time units are all class time units.

- $l_\alpha^u$: indicates the $u$th lecture time unit in section $\alpha$.

- $t_\alpha^v$: indicates the $v$th tutorial time unit in section $\alpha$.

Coefficients:

- $C_{ij} = \begin{cases} 1 & \text{if } i, j \text{ are in different campuses} \\ 0 & \text{if } i, j \text{ are in same campus} \end{cases}$

- $S_i$: course rating of $i$

  $T_i$: time rating of $i$ $S_i, T_i = \begin{cases} 1 & \text{Most liked} \\ ... & \\ 5 & \text{even} \\ ... & \\ 10 & \text{Most disliked} \end{cases}$

- $M$: large constant, set $M = 20$.

- $f$: penalty coefficient 1 for $y_{ij}$.

- $d$: penalty coefficient 2 for $z_k$.

- $e$: penalty coefficient 3 for $w_k$.

Variables:

- Decision Variable

$$x_i = \begin{cases} 1 & \text{if class time unit } i \text{ is taken} \\ 0 & \text{otherwise} \end{cases}$$

- $$y_{ij} = \begin{cases} 1 & \text{if a switch from class time unit } i \text{ to } j \text{ occurs} \\ 0 & \text{otherwise} \end{cases}$$

- $$z_k = \begin{cases} 1 & \text{if there is a class on day } k \\ 0 & \text{otherwise} \end{cases}$$

- $$w_k = \begin{cases} 1 & \text{if the total class time is overload} \\ 0 & \text{otherwise} \end{cases}$$

## 3.4 Constraints

- **Conflict Free**

$$x_i + x_j \leq 1, \text{for } \forall i, j \text{ have a conflict.}$$

$i, j$ have a conflict when one of the following cases occurs:

Case 1: $i, j$ are at the same time slot;

Case 2: $i, j$ are at the adjacent time slot but on different campuses

By adding a conflict, any two conflicted class time units cannot be chosen at the same time.

Example 1: $x_1$ and $x_2, x_4$ and $x_5$ have a conflict since they are in the same time slot. $x_1$ and $x_3$ also have a conflict since they are adjacent time slot in different campuses. In Figure 1, {$x_1, x_4, x_7, x_{10}$} is a feasible solution.

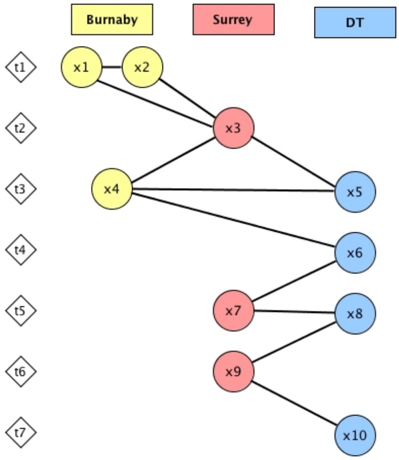


Figure 1: Example 1

- **Switch Counting**

$$x_i - x_{i+1} - ... - x_{j-1} + x_j - y_{ij} \leq 1, \text{for } \forall i, j \in D_k, k = 1, 2, 3, 4, 5$$

Example 2: In Figure 2, If $x_1, x_4, x_7, x_{10} = 1$ and the rest $x_i = 0$, then only $y_{14} = y_{47} = y_{710} = 1$. Note that $y_{17} = 0$ even $x_1 = x_7 = 1$.

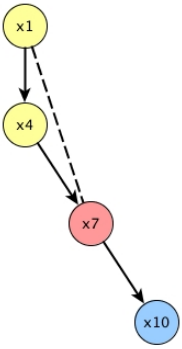


Figure 2: Example 2

- **Selection Tree**

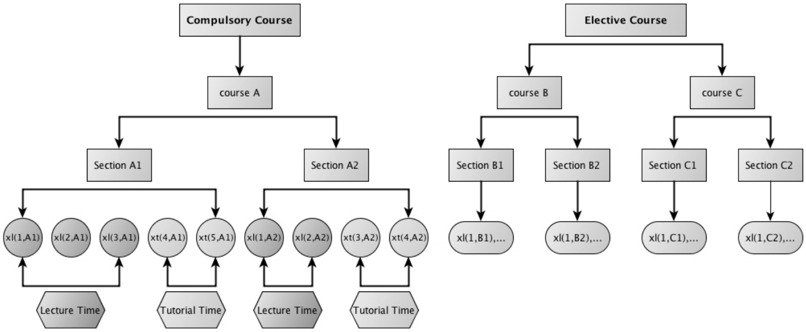


Figure 3: Course Selection Tree

For any section $\alpha$ :

$$x_{l^1_\alpha} = x_{l^u_\alpha}, \forall u \neq 1$$

$$x_{l^1_\alpha} = \sum_{\text{all} v} x_{t^v_\alpha}$$

For any compulsory course $Q_p$:

$$\sum_{\alpha \in Q_p} x_{l^1_\alpha} = 1$$

For any elective course $Q_q$:

$$\sum_{\alpha \in Q_q} x_{l^1_\alpha} \leq 1$$

In the case of selecting $m$ courses from $n$ electives: $m \leq n$, and $m, n \geq 1$

$$\sum_{\alpha \in \{Q_1, \dots Q_n\}} x_{l^1_\alpha} = m$$

Example 3: Course $A$ has two sections $A_1, A_2$. Section $A_1$ has 3-hour-lecture and 2 tutorials, notated by $x_{l^1_{A_1}}$, $x_{l^2_{A_1}}$, $x_{l^3_{A_1}}$, $x_{t^1_{A_1}}$, $x_{t^2_{A_1}}$

(1) The basic logic is that all lecture time units can be either chosen all or chosen none. Moreover, if the lecture time unit has chosen, one of the corresponding tutorials must be chosen; if the lecture time unit of section $A_1$ is not chosen, all the corresponding tutorials are not allowed to be chosen. So,

$$x_{l^1_{A_1}} = x_{l^2_{A_1}} = x_{l^3_{A_1}} = x_{t^1_{A_1}} + x_{t^2_{A_1}}$$

(2) Since we already have the basic logic, when we want to choose all related class time units of a section, it can be solved easily by just taking the first lecture time unit of the section.

If course $A$ is compulsory, then one of its sections must be taken.

$$x_{l^1_{A_1}} + x_{l^1_{A_2}} = 1$$

If course $A$ is elective, then at most one of its sections can be taken, then

$$x_{l^1_{A_1}} + x_{l^1_{A_2}} \leq 1$$

- **Penalty Score With Soft Constraints**

  Penalize on any day when there is a class, because traveling from home to school is also time consuming.

$$\sum_{i \in D_k} x_i \leq M z_k, \text{ for } k = 1, 2, ..., 5$$

  Penalize on any day when class time is over 6 hours.

$$\sum_{i \in D_k} x_i \leq 6 + M w_k, \text{ for } k = 1, 2, ..., 5$$

# 4 Model

A summary of the UCSP model in mathematical notation.

$$\text{Minimize } f \sum_{i,j} C_{ij} y_{ij} + \sum_{i} (S_i + T_i) x_i + \sum_{k} (d z_k + e w_k)$$

Subject to:

$$x_i + x_j \leq 1 \text{ ,for } \forall i, j \text{ have a conflict}$$

$$x_i - x_{i+1} - ... - x_{j-1} + x_j - y_{ij} \leq 1, \text{ for } \forall i, j \in D_k, k = 1, 2, ..., 5$$

$$x_{l^1_\alpha} = x_{l^u_\alpha}, \forall u \neq 1$$

$$x_{l^1_\alpha} = \sum_{\text{all } v} x_{t^v_\alpha}$$

$$\sum_{\alpha \in Q_p} x_{l^1_\alpha} = 1$$

$$\sum_{\alpha \in Q_q} x_{l^1_\alpha} \leq 1$$

$$\sum_{\alpha \in \{Q_1, \dots Q_n\}} x_{l^1_\alpha} = m$$

$$\sum_{i \in D_k} x_i \leq M z_k, \text{ for } k = 1, 2, ..., 5$$

$$\sum_{i \in D_k} x_i \leq 6 + M w_k, \text{ for } k = 1, 2, ..., 5$$

## 5 Case Study

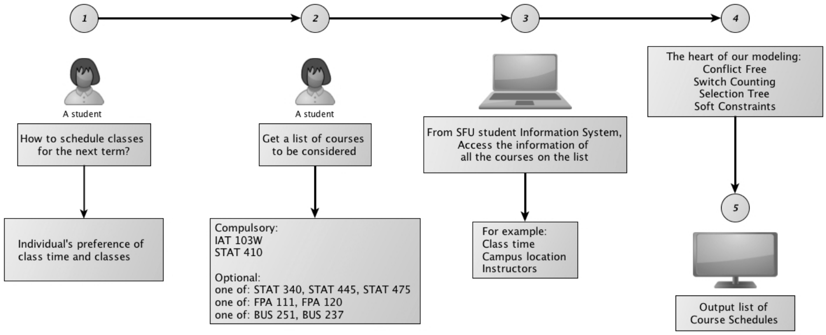


Figure 4: The System Process

In this project, our motivation is to develop a model to solve the UCSP problem for Simon Fraser University students. We collected sample data for the 2013 spring semester from the Student Information System (SIS) to test the derived model. This study shows that the derived model easily solves the problem producing an optimal solution in very reasonable time.

Our database is a repository of student data. From this database, the system can extract a student profile, which contains all the information needed for course scheduling. This information involves a set of courses in which a student wishes to enroll for the next term, including parameters for each course, such as the class time unit, instructors and campus location. The student profile can also capture other information about the student, such as special needs or interests.

This case study arises from a third years Operation Research Program student. The student has to plan his/her schedule of classes for the 2013 Spring term. Based on his/her consideration, our system needs to help him to obtain an optimal solution.

## 5.1 Input

The course list includes a total of nine different courses. There are two compulsory courses and three different types of elective courses. Using our model, the final timetable must contain both two compulsory courses and one of each type of elective courses. Table 1 shows the course list.

| | | |
|---|---|---|
| **Compulsory Course** | | |
| | IAT 103 | Design Communication and Collaboration |
| | STAT 410 | Statistical Analysis of Sample Surveys |
| **Elective Course** | | |
| One of | STAT 340 | Introduction to Statistical Computing and Exploratory Data Analysis |
| | STAT 445 | Applied Multivariable Analysis |
| | STAT 475 | Applied Data Analysis |
| One of | FPA 111 | Issues in the Fine and Performing Arts |
| | FPA 120 | Introduction to Dance Forms: Contemporary and Popular |
| One of | BUS 251 | Financial Accounting I |
| | BUS 237 | Information Systems in Business |

Table 1: Course List

## 5.2 Output

Due to various constraints, especially for some courses that have many different sections at different times, or even on different campuses, the derived model contains approximately 1400 variables and 1500 constraints. By using the Solver, it takes about 3 seconds to produce the optimal solution. This study has analyzed four different cases.

We control the preference rate of each course to be 0. In other words, the preference rate of each course has no influences on the objective. Meanwhile, we set the preference rate for each time period, for instance, the rate of the period which from 8:30 a.m. to 9:30 a.m. is 10. The course schedule is shown in Figure 5 (B=Burnaby, S=Surrey, D=Downtown, T=Tutorial, BUS 251(2)=Course Section 2 of BUS 251).

From Figure 5, although the course schedule is efficient and most of the courses taken are in the preferred time periods, this course schedule does not contain more preferred elective courses.

Case 1 (Time Preferred, no Penalty Scores):

Table 2: Case 1: Time Preferred

| Course | Course Rate | Time | Time Rate |
|---|---|---|---|
| FPA 111 | 0 | 8 | 10 |
| FPA 120 | 0 | 9 | 10 |
| IAT 103 | 0 | 10 | 10 |
| BUS 237(1) | 0 | 11 | 10 |
| BUS 237(2) | 0 | 12 | 1 |
| BUS 237(3) | 0 | 13 | 1 |
| BUS 251(1) | 0 | 14 | 1 |
| BUS 251(2) | 0 | 15 | 1 |
| BUS 251(3) | 0 | 16 | 1 |
| MATH 308 | 0 | 17 | 1 |
| STAT 340 | 0 | 18 | 10 |
| STAT 410 | 0 | 19 | 10 |
| STAT 445 | 0 | 20 | 10 |
| STAT 475 | 0 | 21 | 10 |
| f | 0 | | |
| d | 0 | | |
| e | 0 | | |

| Case 1 | MON | TU | W | TH | FRI |
|---|---|---|---|---|---|
| 8:30-9:30 | STAT 445 T1-B | | | | |
| 9:30-10:30 | | | | | |
| 10:30-11:30 | | | | | |
| 11:30-12:30 | | | | | |
| 12:30-13:30 | STAT 445-B | | STAT 445-B | | |
| 13:30-14:30 | STAT 445-B | | | | |
| 14:30-15:30 | | BUS 251(2)-S | STAT 410 T1-B | IAT 103-S | STAT 410-B |
| 15:30-16:30 | | BUS 251(2)-S | STAT 410-B | IAT 103-S | STAT 410-B |
| 16:30-17:30 | | BUS 251(2) T3-S | | IAT 103-S | |
| 17:30-18:30 | | | | | |
| 18:30-19:30 | FPA 111-D | | | | |
| 19:30-20:30 | FPA 111-D | | | | |
| 20:30-21:30 | FPA 111 T1-D | | | | |
| 21:30-22:30 | | | | | |

Figure 5: Course Schedule 1

We control the preference rate of each time period to be 0, which means that the preference rate of each time period does not relate to the objective. The course schedule is shown in Figure 6. In the schedule, most of the preferred elective courses are included. However, this course schedule is not as compact as that of case 1.

Case 2 (Course Preferred, no Penalty Scores):

| Case 2 | MON | TU | W | TH | FRI |
|---|---|---|---|---|---|
| 8:30-9:30 | | | | | |
| 9:30-10:30 | | | | STAT 475-B | |
| 10:30-11:30 | BUS 237(2)-S | STAT 475-B | | STAT 475-B | |
| 11:30-12:30 | BUS 237(2)-S | STAT 475 T1-B | | | |
| 12:30-13:30 | | | | | |
| 13:30-14:30 | | | | | |
| 14:30-15:30 | | | STAT 410 T1-B | IAT 103-S | STAT 410-B |
| 15:30-16:30 | BUS 237(2) T5-S | | STAT 410-B | IAT 103-S | STAT 410-B |
| 16:30-17:30 | | | | IAT 103-S | |
| 17:30-18:30 | | | | | |
| 18:30-19:30 | FPA 111-D | | | | |
| 19:30-20:30 | FPA 111-D | | | | |
| 20:30-21:30 | FPA 111 T1-D | | | | |
| 21:30-22:30 | | | | | |

Figure 6: Course Schedule 2

Table 3: Case 2: Course Preferred

| Course | Course Rate | Time | Time Rate |
|---|---|---|---|
| FPA 111 | 10 | 8 | 0 |
| FPA 120 | 1 | 9 | 0 |
| IAT 103 | 10 | 10 | 0 |
| BUS 237(1) | 10 | 11 | 0 |
| BUS 237(2) | 1 | 12 | 0 |
| BUS 237(3) | 10 | 13 | 0 |
| BUS 251(1) | 10 | 14 | 0 |
| BUS 251(2) | 10 | 15 | 0 |
| BUS 251(3) | 10 | 16 | 0 |
| MATH 308 | 10 | 17 | 0 |
| STAT 340 | 10 | 18 | 0 |
| STAT 410 | 10 | 19 | 0 |
| STAT 445 | 10 | 20 | 0 |
| STAT 475 | 1 | 21 | 0 |
| f | 0 | | |
| d | 0 | | |
| e | 0 | | |

Case 4 (Time and Course Preferred, with Penalty Scores):

Both preference rates of courses and time periods are tested in this case, and this rating system is a combination of the rating systems of the first two cases. The course schedule is shown in Figure 7.

| Case 3 | MON | TU | W | TH | FRI |
|---|---|---|---|---|---|
| 8:30-9:30 | | | | | |
| 9:30-10:30 | | | | STAT 475-B | |
| 10:30-11:30 | BUS 237(2)-S | STAT 475-B | | STAT 475-B | |
| 11:30-12:30 | BUS 237(2)-S | | | | |
| 12:30-13:30 | | | | | |
| 13:30-14:30 | | | | | |
| 14:30-15:30 | | | STAT 410 T1-B | IAT 103-S | STAT 410-B |
| 15:30-16:30 | BUS 237(2) T5-S | | STAT 410-B | IAT 103-S | STAT 410-B |
| 16:30-17:30 | | STAT 475 T2-B | | IAT 103-S | |
| 17:30-18:30 | | | | | |
| 18:30-19:30 | FPA 111-D | | | | |
| 19:30-20:30 | FPA 111-D | | | | |
| 20:30-21:30 | FPA 111 T1-D | | | | |
| 21:30-22:30 | | | | | |

Figure 7: Course Schedule 3

According to Figure 7, the course schedule is similar with that of the second case expect the tutorial of STAT 475. For the schedule of case 2, the system selects tutorial 1 which improves the schedule more compact. And for this case, the system selects tutorial 2.

Case 3 (Time and Course Preferred, no Penalty Scores):

Table 4: Case 3: Consider Time and Course

| Course | Course Rate | Time | Time Rate |
|---|---|---|---|
| FPA 111 | 10 | 8 | 10 |
| FPA 120 | 1 | 9 | 10 |
| IAT 103 | 10 | 10 | 10 |
| BUS 237(1) | 10 | 11 | 10 |
| BUS 237(2) | 1 | 12 | 1 |
| BUS 237(3) | 10 | 13 | 1 |
| BUS 251(1) | 10 | 14 | 1 |
| BUS 251(2) | 10 | 15 | 1 |
| BUS 251(3) | 10 | 16 | 1 |
| MATH 308 | 10 | 17 | 1 |
| STAT 340 | 10 | 18 | 10 |
| STAT 410 | 10 | 19 | 10 |
| STAT 445 | 10 | 20 | 10 |
| STAT 475 | 1 | 21 | 10 |
| f | 0 | | |
| d | 0 | | |
| e | 0 | | |

Table 5: Case 4: Consider with the Penalty Scores

| Course | Course Rate | Time | Time Rate |
|---|---|---|---|
| FPA 111 | 10 | 8 | 10 |
| FPA 120 | 1 | 9 | 10 |
| IAT 103 | 10 | 10 | 10 |
| BUS 237(1) | 10 | 11 | 10 |
| BUS 237(2) | 1 | 12 | 1 |
| BUS 237(3) | 10 | 13 | 1 |
| BUS 251(1) | 10 | 14 | 1 |
| BUS 251(2) | 10 | 15 | 1 |
| BUS 251(3) | 10 | 16 | 1 |
| MATH 308 | 10 | 17 | 1 |
| STAT 340 | 10 | 18 | 10 |
| STAT 410 | 10 | 19 | 10 |
| STAT 445 | 10 | 20 | 10 |
| STAT 475 | 1 | 21 | 10 |
| f | 40 | | |
| d | 100 | | |
| e | 100 | | |

Keep all preference rates the same as case 3, and then add $f, d, e$, which are penalty scores and equal to 40, 100, 100 respectively, in this case. The course schedule is shown in Figure 8:

| Case 4 | MON | TU | W | TH | FRI |
|---|---|---|---|---|---|
| 8:30-9:30 | | | | | |
| 9:30-10:30 | STAT 445 T2-B | | | | |
| 10:30-11:30 | | | | | |
| 11:30-12:30 | | | | | |
| 12:30-13:30 | STAT 445-B | | STAT 445-B | | |
| 13:30-14:30 | STAT 445-B | | | | |
| 14:30-15:30 | | | STAT 410 T1-B | IAT 103-S | STAT 410-B |
| 15:30-16:30 | | | STAT 410-B | IAT 103-S | STAT 410-B |
| 16:30-17:30 | | | | IAT 103-S | |
| 17:30-18:30 | | | BUS 251(3)-B | | |
| 18:30-19:30 | FPA 111-D | | BUS 251(3)-B | | |
| 19:30-20:30 | FPA 111-D | | | | |
| 20:30-21:30 | FPA 111 T1-D | | BUS 251(3) T2-B | | |
| 21:30-22:30 | | | | | |

Figure 8: Course Schedule 4

From Figure 8, there is no class on Tuesday. The reason is that when one day has a class, an increase of penalty scores occurs in the solution. In order to minimize the penalty score, the system will make day off as much as possible.

## 6 Future Development

The model developed above gives a framework for solving the UCSP problem, but many assumptions were made to reduce the overall complexity of the model. Future versions of the model will replace these assumptions with new model components which take their effects into account. In addition, there are other limitations which can be overcome to expand the breadth of the solution.

At present, it is assumed that the user knows their course selection strategy, which means the course list is given. Moreover, the user has to provide their preference coefficients. It might require some experiences of the user to set reasonable coefficients. The second limitation is the model can only provide a one-term timetable. This means that if the student asks for a one-year timetable, this model would unable to handle the task.

For our further improvement, we consider to get help from some professional experts' work to solve these limitations. Since Kun Wu [18] attempted to apply computing method to generate a multiple-term planning for students and meet all the faculty requirements. Moreover, Hori [11] pointed out universities could use the Google search method to analyze and record users' search interests and habits. John J. [8] also mentioned an idea of studying the student's enrollment demand and providing the support for university decision makers.

With these additional constraints and modifications, the model may become more flexible and functional in which can let more students try it out and it can be publicly available.

## 7 Conclusion

At the start of this project, we intended to investigate whether the UCSP problem could be solved by a linear program. Fortunately, the model presented does completely solve all the issues present in the problem definition. The Solver-based spreadsheet we developed is able to find a solution that is optimal for the conditions set up in the model.

In this study, we have constructed a curriculum timetabling model for an individual students to minimize the cost of inter-campus travel time and maximize the student's personal course selection preferences. The model can generate an optimal result in a very reasonable time when the course list is not large. The case study has been tested and it shows an apparent improvement of the results by using this UCSP model.

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