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A MULTI-OBJECTIVE DECISION MAKING MODEL FOR CLASS SELECTION PROBLEM: A CASE STUDY

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Abstract: Educational institutions generally present a timetable to students in which the scheduling of courses and classes have been arranged before. Generating an appropriate timetable in which all classes do not conflict each other is quite difficult. Students use this timetable to choose the courses and classes according to their requirements. A selected course class may be conflict with another selected one in timetable. Therefore, students are generally forced in selecting the classes without course conflict or minimum and acceptable course conflict. In this study a computer aided system for engineering students of Industrial Engineering Department at Gazi University is proposed to define the classes for selected courses. The system takes the courses from users and presents them appropriate classes by using a mathematical model in background. The aims of the mathematical model are minimizing the course conflict, assigning student to classes desired by department and minimizing total days in which the student takes courses. Consequently, an easy way is proposed to students in selecting course classes by improving a multi-objective decision making model and a case study is applied.

Keywords**:** Student sectioning problem, decision making model, individual student schedule

Introduction

Educational institutions usually present a timetable to students in which the scheduling of courses and classes have been arranged before. This situation leads to a problem in all education period named as course timetabling. The course timetabling mainly deals with assigning lectures to time periods and lecture room in such a way that a set of constraint satisfy (Amintoosi and Haddadnia, 2004). Course timetabling an exhausting and time consuming for the educational institutions, must be done for each semester frequently (Babbaei et al., 2015). Therefore, the stated problem has been widely studied by researchers and several solution approaches have been developed based on different methods such as operational research, intelligent novel and metaheuristics. The recent developments about the course timetabling can be found in the review study proposed by Babbaei et al. (2015). Although many useful solution approaches have been developed for course timetabling problem, obtaining a perfect timetable in all respect is very hard. Students generally schedule their courses by selecting the classes for desired courses from the timetable prepared by institution. The repetitive and elective courses of a student can lead to course conflict which should be minimized by selecting appropriate classes. This issue brings out the individual student scheduling problem which can be defined as assigning students to classes with respecting course conflict, student request and fullness of classes.

Academic timetabling problems can be categorized as school timetabling, course timetabling and exam timetabling (Müller and Murray, 2010). Student sectioning problem generally resides outside of this categorization because of considering as a sub problem of course timetabling. The stated problem has received considerable attention since it is necessary to define the students' classes without course conflict or minimum conflict and commonly occurred in educational environment. Considering the studies directly related to the

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stated problem, Carter (2000) described a comprehensive course timetabling and student scheduling system that was applied at a university. In that study students chose their requirements, and the system tries to find the best timetable to maximize the number of satisfied requests. A different student sectioning algorithm based on fuzzy c-Means method was proposed by Amintoosi and Haddadnia (2004). Fuzzy function evaluates the produced clusters balancing sections and students' schedules similarity within each section. Müller et al. (2007) proposed an enterprise system for automated construction of course timetables beside creation and modification of individual student schedules. Müller and Murray (2010) proposed three approaches based on student sectioning. These were applied during the course timetabling, batch sectioning after a complete timetable and online sectioning for making additional changes. Applications of practical problems were examined beside the actual data. Kristiansen and Stidsen (2012) proposed a heuristic based on adaptive large neighborhood search algorithm for student sectioning at a high school. Kristiansen and Stidsen (2014) also improved a heuristic based on the same algorithm for elective course sectioning problem after defining integer programming model of the problem. Dostert et al. (2015) dealt with complexity analysis and an algorithmic approach to student sectioning in existing timetables. They model a basic version of the sectioning problem that was polynomial solvable and identify single additional constraints that increase the problem's complexity to NP-hardness.

This study deals with individual student scheduling problem in existing timetable. Aim of the study is assisting to students in selecting the classes for minimizing course conflict and the number of days on which selected classes are located, while maximizing the department satisfactory (by assigning the students to classes equally as much as possible). Therefore, a computer aided system, which takes the courses from a student and presents him/her appropriate classes by using a mathematical model in background, is improved. The proposed computer aided system is tested at Industrial Engineering Department of Gazi University successfully. The rest of the paper is organized as follows: problem definition and current state for the case study is given in the next section. Section 3 gives information about the proposed computer aided system and defines the mathematical formulation of the problem. Lastly conclusions and comments are given in Section 4.

Problem Definition

Student sectioning problem can be defined as a sub problem of course timetabling. The stated problem deals with assigning student to particular sections (classes) of courses with respect to some requirements (students' and institution's requirements) and constraint (e.g., a student cannot attend two classes that are performed simultaneously) (Müller and Murray, 2010). On the other hand, individual student schedule tries to generate a timetable for only one student in which the student's requests are satisfied and course conflicts are minimized, and acceptable. The main issue of the stated problem is determining the appropriate combination of the course classes. Obtaining a perfect schedule for a student is nearly impossible since combination of the course classes can only be formed by using the general timetable proposed by educational institutions. Although the stated problem is named individual student scheduling, the requests of the educational institutions should be considered, such as allocating students to classes of a course equivalently as much as possible. The individual student scheduling problem considered in this study determines the classes with three aims: minimizing course conflicts, assigning students to classes equivalently as much as possible and minimizing the number of days on which selected classes are located.

Examining the current situation in Industrial Engineering Department at Gazi University will be helpful to identify the problem more clearly. In the stated department of the school, students are sectioned according to their education (there are two education named first and second education) and ID number. Generally two different classes for a course in each education is proposed to students. The students whose ID number is odd are assigned to a class, and the other students are assigned to another class according to their education. When repetitive or elective courses are taken according to the stated rule, the courses may be conflict with each other. In this situation although students can choice their classes to minimize course conflict without considering the stated rules, they are also forced in determining the best combination of the classes. Continuity of a student for a class is one of the requirements for the success of him. The continuity cannot be smaller than 70% at the stated institution. Therefore, selecting two different classes having conflict ratio greater than 30% is not possible theoretically. The conflict ratio between classes i and j, CR_{ij}, is computed by using the following equation:

$$CR_{ij} = \frac{s_{ij}}{t_i + t_j} \tag{1}$$

In this equation t_i and t_j are time intervals for class i and j respectively, and s_{ij} represents conflicting time interval for these classes. Consider classes i and j which are located on the same day, and whose schedule is given in Figure 1. As is seen on this figure, s_{ij}, t_i and t_j equal to 1, 2, and 3 respectively. The student is able to select these two classes together since the conflicting ratio is computed as 0.2.

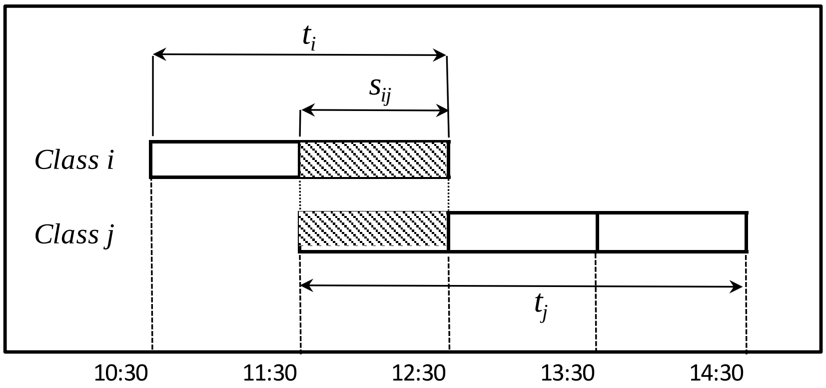


Figure 1. Illustrative example of class conflict.

This paper presents a computer aided system, which solves the stated problem by using a mathematical model in background. The first aim of the mathematical model is minimizing course conflicts, while secondly assigns students to classes with respecting department's requests. The last aim of the mathematical model is minimizing the days on which at least one course is selected.

Solution Approach

As stated earlier, a computer aided system which determines the appropriate classes for the selected courses is presented. The system takes the courses from user, and generates the integer linear programming model of the problem and solves it by using CPLEX 10.2 solver. The system presents the list of appropriate classes and the schedule of this list to the user after solution process. The mathematical formulation of the problem is given below.

Mathematical Model

Notations

C : Set of required courses { $c \in C$ }
S : Set of classes { $s \in S$ }
CS_c : Set of classes of course c { $s \in CS_c$ }
D_s : Set of classes whose conflicting ratio between class *s* is greater than 0% and smaller than 30%
T_s : Set of classes whose conflicting ratio between class *s* is greater than 30%
ON : Set of classes which are suitable for student's ID, but not for his education { $s \in ON$ }
NS : Set of classes which are suitable for student's education, but not for his ID { $s \in NS$ }
NN : Set of classes which are not suitable for student's education and ID { $s \in NN$ }
I : Set of days { $i \in I$ }
G_i : Set of classes at day *i* { $s \in G_i$ }
x_s : Binary variable with value 1 if class *s* is selected
f_{sh} : Binary variable with value 1 if class *h* and *s* are selected together
y_i : Binary variable with value 1 if the student selects at least one class on day *i*
φ : Sufficiently big number

Model

$$\min\left(\varphi\cdot(\sum_{s\in S}\sum_{\substack{h\in D_s\\ s<h}} f_{sh})+(\sum_{s\in ON}x_s+\sum_{s\in NS}x_s+\sum_{s\in NN}2\cdot x_s)+\frac{1}{\varphi}(\sum_{i\in I}y_i)\right) \tag{2}$$

Subject to:

$$\sum_{s \in CS_c} x_s = 1, \qquad \forall c \in C \tag{3}$$

$$x_s + x_h \leq 1 + f_{sh}, \qquad \forall s \in S; \forall h \in S; s < h \tag{4}$$

$$f_{sh} = 0, \qquad \forall s \in S; h \in T_s \tag{5}$$

$$\sum_{h \in D_s} f_{sh} \leq 1 + \varphi \cdot (1 - x_s), \qquad \forall s \in S \tag{6}$$

$$\sum_{s \in G_i} x_s \leq \varphi \cdot y_i \qquad \forall i \in I \tag{7}$$

$$x_s \in \{0,1\}, \qquad \forall s \in S \tag{8}$$

$$f_{sh} \in \{0,1\}, \qquad \forall s \in S; \forall h \in S; s < h \tag{9}$$

$$y_i \in \{0,1\}, \qquad i \in I \tag{10}$$

Equation (2) is the objective function of the model which includes three goals: a) minimizing course conflicts, b) assigning the student to suitable classes by considering department's requirements, and c) minimizing the number of days on which at least one class is located. Constraint set (3) ensures that the student takes a class for each course. Constraint set (4) states that if both class h and s are selected, then the variable f_{sh} must have the value 1. Constraint set (5) prevents selection of two classes whose conflict ratio is bigger than 30%. Constraint set (6) means that a selected class cannot conflict more than one another selected classes. While constraint set (7) gives the proper values to variables y_i, constraint sets (8)-(10) define sign restrictions.

System Architecture

The course timetable which was previously formed by educational institution must be defined in the program for making computer aided system ready to use. In the developed software, definition of courses and declaration of their timetables are done by using the course and class identification modules. The windows of these modules are given in Figure 2.

(a) Course identification module (b) Class identification module

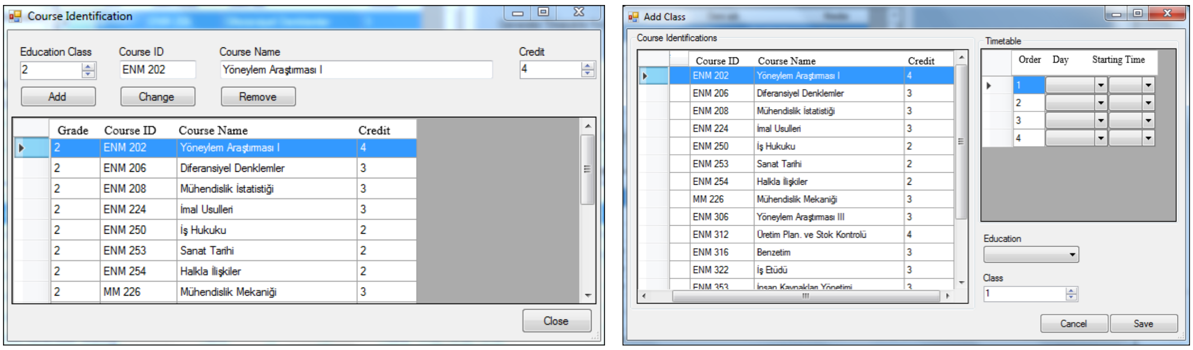


Figure 2. Class and course identification module

After defining all courses and their timetables which are present in the current semester, computer aided system can be easily used by students. A student firstly selects his education and ID type, and then chooses his courses from the list which includes all of courses. After clicking the button named "Select Classes and Show on Timetable", the software generates the mathematical model of the problem, and solves it by using CPLEX 10.2 solver in background. Windows which are used for these functions are presented in Figure 3.

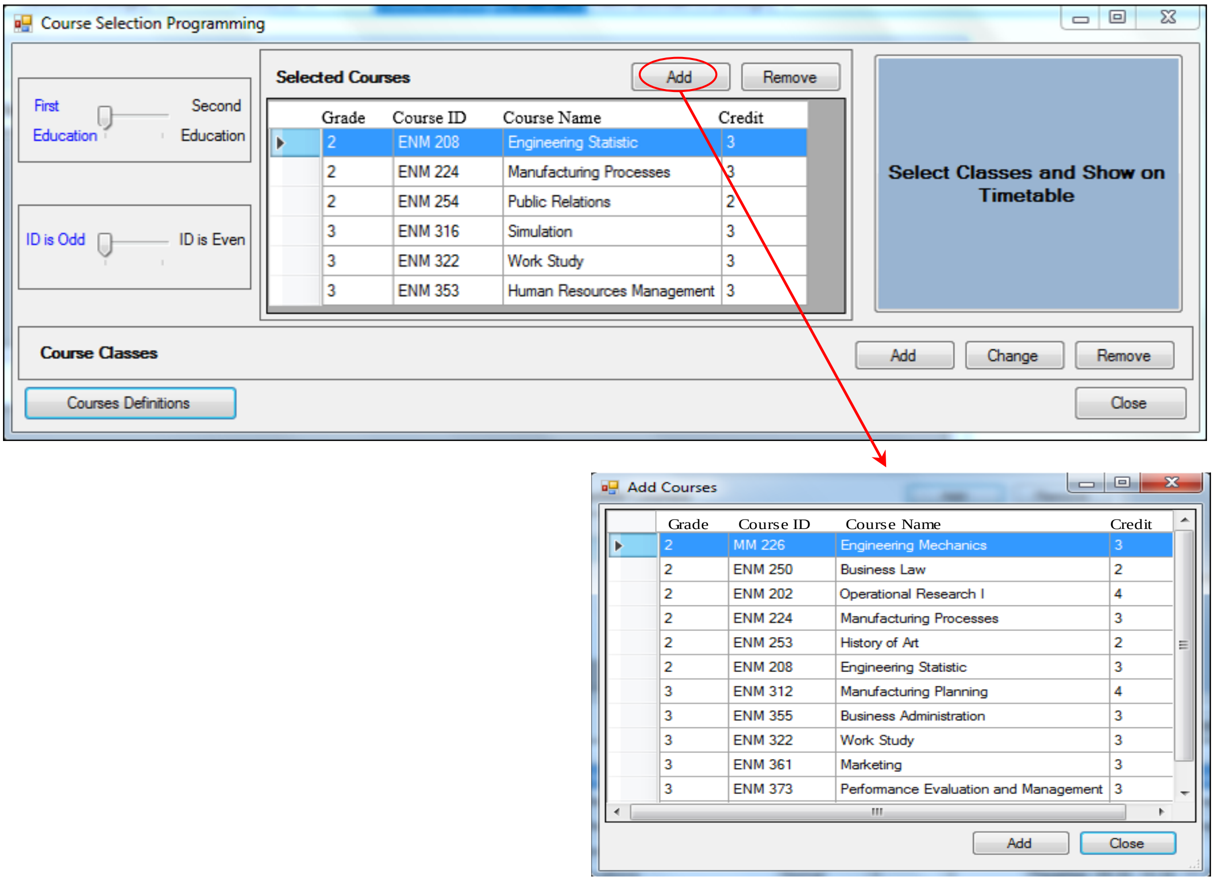
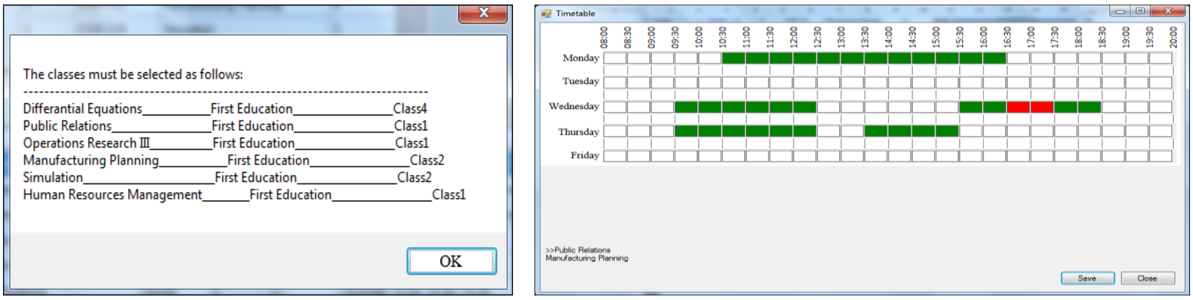


Figure 3. Course selection module

The mathematical model is solved by using CPLEX 10.2 solver and the solution is presented to user as an information about the selected classes. The schedule which is formed according to mathematical model result is generated as an output of the decision making model. In order to present an illustrative example, a schedule for a student from the first education with an odd ID number is generated by using the software. The student desires six different courses. The outputs of the software for this student are presented in Figure 4.



(a) Selected classes

(b) Timetable of the selected classes

Figure 4. An illustrative example for software's outputs

As seen on Figure 3(a), all classes are selected from the first education and the classes are assigned to the student according to depatment's requirements as much as possible. The selected classes are distrubuted into three days by decreasing course conflicts. As seen on the example, the proposed multi-objective decision making model easily determines the best combination of the classes in a short time.

Conclusions

Although course timetabling problem has been widely studied by the researchers and several solution approaches have been developed, obtaining a good timetable in all respect is one of challenging problems. Student sectioning problem which is a sub problem of course timetabling is commonly occurred in most of large educational institutions. Assigning students equivalently to classes as much as possible is important for educational institutions to balance the number of students of classes. The number of study about student sectioning problem is limited, although the stated problem arises frequently in most of large educational institutions. The individual student scheduling problem can be defined as an important sub problem of student sectioning problem. This study proposes a solution method for individual student sectioning problem by improving a computer software. It has been seen that the proposed mathematical model can be easily solved, and the software is helpful to students to select most appropriate combination of classes.

In future research, several constraints can be added to mathematical model by using students' and institutions' requirements. The model can be adapted to another institution with considering their requirements.

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