A Student-Oriented Class-Course Timetabling Model with the Capabilities of Making Good Use of Student Time, Saving College Budgets and Sharing Departmental Resources Effectively

Chin-Ming Hsu¹ and Hui-Mei Chao²

¹ Department of Information Technology, Kao Yuan University, Taiwan, R.O.C.
² Department of Electronic Engineering, Kao Yuan University, Taiwan, R.O.C.
chinming.hsu@cc.kyu.edu.tw and huimei.chao@cc.kyu.edu.tw

Abstract

This paper proposes a student-oriented class-course timetabling model to make good use of student time, save college budgets, and share departmental resources effectively. To achieve these goals, the study proposes a heuristic driven process coupled with two fitness functions to satisfy students’ needs for taking or retaking certain courses without delaying their graduation; the proposed method balances class sizes to decrease the number of elective courses opened to the students; and the research formulates the allocating rules for utilizing the classrooms and the laboratories to ensure that the resources can be shared effectively. From the experimental results, the minimum and maximum average satisfaction for all students’ needs is 0.8 and 0.9, respectively, where the lowest score is 0.7 and the highest score is 1. These results show that the difference of each student’s satisfaction is small and students’ expectations on taking specific subjects can be satisfied as nearly as possible.

Keywords: Class-course timetabling, heuristic driven process and fitness function.

1. Introduction

For an individual department at a university, scheduling class-course timetables is an important administrative task because it has to be arranged every semester. This scheduling problem generally allocates all students’ courses to appropriate timeslots with the limited resources, including facilities, classrooms, and laboratories. In Taiwan, this task is specifically complicate and difficult because of multi-educational systems, such as four-year undergraduate program, four-year evening-class college program, graduate school program, and two-year college program, existing in an academic department. Commonly, each educational system handles different class-course timetabling task; each professional teacher has different preferences on teaching timeslots; each student has to take (or retake) different courses in a semester for not delaying their graduation; and the board of college directors requires making the best use of the college budget. Therefore, inappropriate scheduling class-course timetables may bring some unwilling consequences, such as ineffective sharing departmental resources, increasing college costs by opening too many elective courses, delaying students’ graduation, and lessening faculty expectations on preferred teaching timeslots. Hence, finding an effective and efficient approach for scheduling class-course timetables is an important issue to be solved.

At Electronic Engineering (EE) department of Kao Yuan University (KYU), there are about 40 full-time teachers and 30 classes with totally 200 teaching courses being scheduled every semester. Typically, the number periods per day and days per scheduling week are the same; a weekly timetable is divided into five days (Monday through Friday); and each day is divided into four and eight time periods for the day and evening classes, respectively. The number period for the day classes begins at 8:15 a.m. as the 1st timeslot, 9:15 a.m. as the 2nd timeslot, and so on; the number period for the night classes begins at 06:45 p.m. as the 1st timeslot, 7:35 p.m. as the 2nd timeslot, and so on. Currently, scheduling these numerous courses to specific time periods is often influenced by four factors, including: (1) the course catalog structure changes with the student demands for certain courses every semester; (2) the limited facilities, laboratories, and classrooms affect the effectiveness of allocating available resources; (3) the consideration of each faculty’s preferring teaching timeslots increases the difficulties of the scheduling task; and (4) the organizational policies about requiring the days for each faculty staying at school and requiring the best use of the budgets also increase the difficulties of the scheduling task.

The class-course timetabling task at EE department traditionally relies on human labors. The generated class-
course timetables have the disadvantages of time consuming, inefficient utilization of facility and human resources, biased class-course assignments, and dissatisfaction among students and teachers. Hence, in order to increase the overall performance of the departmental educational system, the authors propose a student-oriented heuristic based class-course-timetable scheduling model with the considerations of students’ needs on retaking different courses for not delaying their graduation, teachers’ preferences on specific teaching time periods, course catalog structure, and the organizational constraints and requirements. The proposed model allows teachers to key in their preferences and allows students to get on the Website keying in their needs of taking specific elective courses and retaking certain courses. The developed heuristic driven process coupled with two fitness functions can make good use of student time, cost down the budget by balancing the class sizes, share university teaching resources effectively, and build the optimal schedules for each class as nearly as possible.

In the following, Section II reviews some related studies. Section III describes the proposed class-course timetabling system. The experimental results are shown in Section IV. Finally, the conclusions and future works are summarized in Section V.

2. Technology background


Three researches [8-10] applied integer programming technology to solve timetabling problem. MirHassani [8] applied 0-1 integer programming approach coupled with a number of operational rules and requirements of Shahrood University, Iran, to enhance the effectiveness of course timetables. Ismayilova et al. [9] proposed a multi-objective 0-1 linear programming model considering both the administration’s and instructors’ preferences and using weight priority to schedule the class-course timetable. Daskalaki and Birbas [10] developed an integer programming formulation for a university timetabling problem, which adopts the university’s constrains to ensure consecutiveness of certain courses. The literatures [11-13] built the schedule and place the teachers to classes simultaneously. Hsiung and Chang [11] proposed a genetic based algorithm for solving the course assigning problem with the consideration of faculty preferences, which has the disadvantage of repeating starting searching point for the proposed genetic algorithm. Beligiannis et al. [12] applied the mathematical model to solve course and time-slot assignment without the consideration of teachers’ preferences. Head and Shaban [13] formulated a heuristic approach for course-student timetabling, which is the student-oriented scheduling model. The literatures [14-15] solved the class-faculty assignment in two stages, which has the advantage of presenting a complicated model as a more comprehensive model by simplifying one problem into two sub-problems. Badri [14] made class-faculty assignments in the first stage and made class-faculty time-slot assignments in the second stage, which seeks to maximize faculty course preferences. Alvarez-Valdes et al. [15] developed a set of heuristic algorithms with Tabu search to solve the problem for building the timetable in planning the third year in which the student would choose different professional orientation (Business Management, Financial Management, Accounting, etc.).

As described above, although the class-course timetabling problem has been widely studied for several decades, there is still no universal scheduling model existing in an academic environment due to specific needs and constraints existing in each individual institute. After reviewing some related literatures, the authors have proposed a two-stage approach for the academic class-course timetabling problem at the EE department of KYU. This paper, the present Stage I, is concerned with designing a student-oriented class-course timetabling model that has the advantages of making good use of student time, decreasing college cost, and sharing departmental resources effectively. Stage II paper [16] is concerned with assigning faculty members to classes for an individual professional department, which is not discussed in this study.

3. Research design and methods

At KYU, the course service division of academic admission office separates a departmental class-faculty-course timetabling system into two parts: one is for the general educational center to schedule the general educational courses; the other one is for an individual
department to schedule the professional courses. Commonly, each class’s general educational courses are scheduled earlier than the professional courses. Before scheduling the general educational courses, the course service division will ask each individual department for listing the preferring timeslots of each class’s general educational courses. The general educational center then complies with each departmental request to schedule the general educational courses. Figure 1 shows the block diagram of the class-course timetabling system, which consists of inputs, class-course scheduling process, and outputs. The class-course scheduling process takes the inputs through the heuristic driven process coupled with two fitness functions to generate the expected class-course timetabling outputs. Each part of the system is described in detail as follows.

3.1. Inputs

The inputs of the class-course timetabling system include faculty preferences, course inventory, and resources. The preferences are the teachers key in their preferring timeslots by the website where seven half days minimally have to be chosen through the website. The course inventory is the list of all requirements and elective courses extracted from the class/course catalog. The resources are the departmental available resources including classrooms and laboratories. Table 1 shows the data structure of the faculty preferring teaching timeslots. At EE department, the teachers are classified into four groups (including navigation electricity, system control, computer engineering, and semiconductor) based on their specialties. As shown in Table 1, unavailable timeslots for a faculty of an individual group are marked. Table 2 illustrates the data structure of the course inventory. In Table 2, all courses are indexed and classified into five groups (including the fields of navigation electricity, system control, computer engineering, semiconductor, and general courses) based on their attributes. The course type is marked as 0 when the course is consecutive, otherwise mark it as 1. Table 3 lists all departmental available classrooms and laboratories. Currently, there are 15 classrooms and 14 laboratories available at EE department of KYU.

| Table 1. The data structure of the faculty preferences |
| Teacher Grp. | Teacher’s Name | Unavailable Time slots |
| Navi. | David Wang | M. T. W. H. F. |
| Syst. | Jim Hsu | . |
| Comp. | A.O. Brown | . |
| Semi. | | . |

| Table 2. The data structure of the course inventory |
| Course Group | Class/Course Title/Hours/Course Type |
| Navi. Ele. | 4EE21/Electronic Lab. / 3 / 0 |
| Syst. Con. | 2EE11/Electronic Lab. / 3 / 0 |
| Comp. Eng. | SEE11/Fund. Navigation/ 3 / 1 |
| Semi. | . |
| Gene. Cour. | . |

| Table 3. The data structure of the resources |
| Classrooms | Laboratories |
| EE101 | VLSI |
| EE102 | Network |
| EE103 | Programming--1 |
| EE201 | Electronic Lab.--1 |
| EE202 | Electronic Lab.--2 |
| . | . |

3.2. Class-course scheduling process

The class-course scheduling process utilizes the heuristic method coupled with two fitness functions to optimize the class-course timetabling outputs. The proposed scheduling process includes four steps: scheduling first two-year professional course’s timeslots, organizing heuristic data, designing fitness functions, and iterative mutations.

Step 1: Scheduling first two-year professional course’s timeslots

According to the course catalog, only the first two years (bachelor and sophomore) of four-year-college program and the first year of two-year-junior-college program have lots of general educational requirements. Therefore, before scheduling the general educational courses, the proposed approach will schedule the junior-year professional courses’ timeslots firstly.
Step 2: Organizing heuristic data

Organizing heuristic data means representing all necessary data sets and constraints as useful information in order to find an optimal solution. In this section, all courses, including required and elective courses, are numbered from 1 to \( n \); all students are numbered from 1 to \( m \); and all teachers are numbered from 1 to \( k \) where \( n, m, \) and \( k \) are the maximum index number of courses, students, and teachers, respectively. The definitions of the data sets and system constraints used throughout in this section are given as follows.

The data sets are:

1. **SNum** \( [i][j] = m \): The student numbered \( m \) is assigned to the \( j \)th class of the \( i \)th year.
2. **CNum** \( [i] = n \): The course numbered \( n \) is assigned to the \( j \)th class of the \( i \)th year.
3. **CAssign** \( [q][p] = n \): The course numbered \( n \) is assigned to the \( p \)th timeslot of the \( q \)th weekday, where \( p = 1 \ldots 40 \), the index number of the timeslot for a week; \( q = 1 \ldots 5 \) (Mon.. Fri.).
4. **Assign** \( [x][p] = n \): The course numbered \( n \) is assigned to the \( p \)th timeslot of the \( x \)th laboratory.
5. **CRetaken** \( [m] = n \): The student \( m \) has marked the course number \( n \) as a retaken course.
6. **Retaken** \( [n] = 1 \): The course numbered \( n \) is marked as a retaken course.
7. **TPref** \( [q][r] = k \): The preferred teaching timeslots chosen by the teacher \( k \) is on \( q \)th weekday; \( r = 0 \) - Morning, \( r = 1 \) - Afternoon.
8. **MutOP** \( [i][j] = n \): The course number \( n \) is assigned to the \( j \)th class of the \( i \)th year and labeled as an mutation operator.

The rules and constraints of scheduling processes are given as follows:

1. For the first year of four-year college program, evenly scheduling each class’s professional courses on weekdays. Currently there are three classes in the bachelor year at EE department of KYU. Generally, only two require and one elective courses need to be scheduled for each class. Therefore, the proposed method would schedule one class’s professional courses on Monday and Thursday, the other on Tuesday and Thursday, and another on Wednesday and Friday. This would help senior students to retake the first year’s professional courses without conflicts.

2. For the second year of four-year college program and the first year of two-year college program, scheduling each class’s professional courses by considering students’ needs on retaking specific courses. In this process, the priority for scheduling consecutive courses such as laboratory courses is higher than that of un-consecutive courses such as theoretical courses. The timeslots for the student needs of retaken courses, including bachelor’s general educational courses and professional courses, are unfilled or assigned to the elective courses as nearly as possible.

3. Scheduling senior courses with the considerations of merging each class’s elective courses, balancing the timeslots of elective courses, scheduling requirements without affecting the students’ needs of retaking certain courses.

4. Whenever scheduling a course to a specific time period, checking the faculty’s preferences on specific teaching timeslots as given in the Table 1.

5. After scheduling a course to a specific timeslot, the corresponding classroom or laboratory is also mapped based on the consideration of fully utilizing a classroom’s and a laboratory’s timeslots.

6. Merging two same classes into one class when the number students are not over 30 students.

Step 3: Designing fitness functions

The fitness function is designed by satisfying different specific constraints and meeting the different needs to evaluate the degree of student satisfaction for their courses assignment. Under the constraints described above, the fitness functions are given as follows.

The satisfaction of the student numbered \( m \) is defined as:

\[
S_m = \frac{TM_m}{p_m} > 0.7
\]

where \( TM_m \) is the total number of the student numbered \( m \) satisfaction matched; \( p_m \) is the total student number keying in their needs.

The average students’ satisfaction (AS) is defined as

\[
AS = \frac{\sum_{i=1}^{m} S_i}{m} > 0.8
\]

Step 4: Iterative mutations

An iterative mutation is based on the label of mutation operator, which gives the algorithm to effectively search another solution to gain better optimization of the class-course timetable. Following shows the procedures of iterative mutations.

For each MutOP do

1. Process1. Select another specific timeslots
2. Process2. Assign the course to the timeslots, if the selected timeslots is allowed to assign a course, \( TM_m = TM_m + 1 \), otherwise, go to Process 1.
End CAssign

End MutOP

3.3. Outputs

The data structure of the outputs contains each class’s course timetable and laboratory’s timetable. Figure 2 gives the 4EE3A class’s course timetable where 4 means four-year college program; EE means electronic
4. Experimental results

The class-course scheduling system is simulated in C programming codes with using MS SQL server as backend database. The proposed method has been tested by Electronic Engineering Department, Kao Yuan University, Taiwan, spring semester, 2008. The proposed approach allows teachers to get on the Web Site to key in at least 7 half-day available teaching timeslots. The satisfaction of student needs is modeled as the 0-1 value. From the experimental results, the difference of each student’s satisfaction is small, where the lowest score is 0.7; the highest score is 1; the minimum and maximum average meeting for all students’ needs is 0.8 and 0.9, respectively. Table 4 shows the differences of the number of elective courses and merged courses for senior-years classes. From Table 4, the number of merged elective courses takes about 50% off the number of original elective courses. This indicates that the proposed method can cost down the courses’ budgets. Table 5 lists the number of laboratories available in the EE department. From Table 5, the laboratory of computer #2 is free all semester; the unused timeslots for VLSI design laboratory are on Tuesday and Friday morning, etc. This shows that the department can preserve the laboratory’s available timeslots for different utilizations such as certificate training courses or other expanding courses.

Table 4 Differences of the number of elective courses and merged elective courses for senior years classes

<table>
<thead>
<tr>
<th>#Courses</th>
<th>4-year college</th>
<th>2-year course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Merged</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 5 the number of labs available in the department

<table>
<thead>
<tr>
<th>TimeSlots</th>
<th>M.</th>
<th>T.</th>
<th>W.</th>
<th>H.</th>
<th>F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microcontr.</td>
<td>MA</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VLSI Design</td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electronic</td>
<td>MA</td>
<td>MA</td>
<td>MA</td>
<td>MA</td>
<td>MA</td>
</tr>
<tr>
<td>Computer #2</td>
<td>MA</td>
<td>MA</td>
<td>MA</td>
<td>MA</td>
<td>MA</td>
</tr>
</tbody>
</table>

Note. M: Morning A: Afternoon
5. Conclusions and Future Works

This paper has proposed a student-oriented class-course scheduling model with the considerations of course catalog structure, students’ needs for retaking different courses without delaying their graduation, and all organizational constraints and requirements. The proposed model allows students to get on the Website keying in their needs of preferring elective courses and retaking certain courses. The proposed approach provides three advantages: (1) The developed heuristic driven process with iterative mutations applies two fitness functions to satisfy students’ needs and make good use of the student time, thereby building the optimal schedules for each class as nearly as possible. (2) By formulating the rules for using the classrooms and laboratories based on the attributes of courses and availabilities of the resources, this makes near-optimal use of university teaching resources as well as increase the overall performance of the educational system. (3) By balancing the class sizes and decreasing the number of elective courses opened to students at an individual department, the cost for opening the courses in a semester is decreased.

This research can be extended to solve the academic based class-course scheduling problem in order to share university resources effectively, save more college budgets, and increase the overall performance of the university’s educational system.

6. References


