A MIP Model for Experimental Courses Scheduling

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Abstract. In this paper, we propose a mixed integer programming (MIP) model to solve the experimental courses scheduling problem. And we use the experimental courses historical data in our information systems to solve the MIP model. The results of the numerical example demonstrate that the proposed model can reach an optimal solution in a short period of time. The MIP model can provide the decision-making support for the experimental courses arrangement.

Keywords: Experimental Course scheduling; Mixed integer programming; Cplex

1. Introduction

The laboratory of colleges and universities is the base of practical teaching, and its management level directly affects the quality of training talents in schools[1]. Therefore, reasonable automated course scheduling is the most effective way to ensure the effective use of laboratory resources. The survey found that the course scheduling process is roughly the same in each school. An initial schedule needs to be built many months by Academic Affairs Office in advance of the term[2]. Then send the schedule to each class teacher, and teachers coordinate the class time of each class according to the student's time, then complete the experimental class scheduling work. Moreover, as the colleges grow and the teaching programs become more complicated, the complexity of class scheduling increases. Manual scheduling is not only time-consuming and laborious, but also poorly regulated, and easy to make mistakes. Therefore, it is necessary to adopt appropriate method to tackle those issues.

In this paper, we focus on how to arrange courses reasonably and advance a mixed integer programming model through which optimal solutions are obtained. The objective function of the study is minimize the total number of days which scheduled the experimental classes. Therefore, it is more favorable to use of the laboratories to arrange practical training at the end of the semester.

2. Related work

The timetabling problem (TTP) is a high-dimensional, non-Euclidean, multi-constraint, combinatorial optimization problem, and is consequently very difficult to solve[3]. This problem has been tried by many approaches. Such as MIP model, dynamic planning[4], backtracking method[5] and many achieved some achievements in practice. Besides, intelligent optimization algorithms such as neural networks, simulated annealing algorithms[6], genetic algorithms[7],and improved particle swarm optimization algorithms[8] have also been used to solve class scheduling problems. Badri et al. formulated a multi objective zero-one course scheduling model. Through an optimization procedure, the model seeks to maximize faculty preferences to courses and times. The model seeks to assign faculty members to courses and to allocate courses to time-blocks simultaneously [9]. Ramon Alvarez-

Valdes et al. developed a computer package to build a course timetable. The optimization process is based on a set of heuristic algorithms [10]. The core of their work is a tabu search procedure for which several strategies have been developed and tested in order to get a fast and powerful algorithm. Producing a schedule for an academic institution is a highly combinatorial problem and a very demanding task. In order to obtain an acceptable solution, human factors also have to be taken into account. Ferland et al. developed a decision support system incorporating efficient optimization procedures and interactive tools to help the user adjust the schedule to his or her specifications. Their system, which is implemented on a micro-computer, is now used each term in two major Canadian universities in Montreal and Sherbrooke [11]. Yen-Zen Wang utilized genetic algorithm methods to deal with the multiple constraints issue. The results of this study indicated a significant reduction in the amount of time required for course scheduling; and the results are more acceptable by teachers [12]. Alain Hertz and Vincent Robert proposed an approach for tackling constrained course scheduling problems. The main idea was to decompose the problem into a series of easier subproblems. Each subproblem is an assignment type problem in which items have to be assigned to resources subject to some constraints. By solving a first series of assignment type subproblems, they build an initial solution which takes into account the constraints imposing a structure on the schedule. Their proposed approach was implemented in practice and has proven to be satisfactory [13]. Wei Shih and James A. Sullivan formulated a multi-period course scheduling problem as a zero-one programming model. Under various constraints, and for a planning horizon of several terms, the model seeks to maximize: (1) the faculty course preferences in assigning faculty members to courses, and (2) the faculty time preferences in allocating courses to time blocks, via a two-stage optimization procedure [14]. Aycan et al. tackles the NP-complete problem of academic class scheduling (or timetabling). Their aim was to find a feasible timetable for the department of computer engineering in Izmir Institute of Technology. The approach focuses on simulated annealing [15].

Course scheduling at colleges is an optimization problem to be solved under multiple constraints. The most important tasks of course scheduling should consider various constraints, such as conflict in teaching hours, meeting teacher preferences, and the continuity of teaching hours, etc[12]. In this paper, a MIP model for experimental course scheduling is proposed. It can flexibly modify the course scheduling strategy according to the user's needs, so it has high portability.

3. Model

The following model is established by abstracting the rule of arranging experiment courses and aiming at the balance of the experiment courses arranged every day. Since the university chosen in this paper does not have the model of arranging experiment courses before, this paper will establish the new model directly, and do not make the comparison between the models.

3.1 Assumptions of The Model

① Don't take into account the special preference of teachers and students for the experiment period;

② Don't take into account the situation that the teacher is unable to attend an experiment class on a temporary basis;

③ Don't take into account the experimental class divided into odd and dual weeks;

④ Don't take into account the external factors which lead to changes in experimental classes, such as holidays, test occupancy, etc.

⑤ Don't take into account the special preferences of teachers and students for the experimental period.

⑥ The capacity of the laboratories is the same every day of the semester.

3.2 Notation

I:The number of experimental courses to be arranged， indexed by $i = 1,2,\ldots,I$；

S: The number of teachers, indexed by $s = 1,2,\ldots,S$；

I_s: The set of experimental courses belong to teacher s, $s = 1,2,\ldots,S$；

$Class$: The set of experimental classes, indexed by $class = 1,2,\ldots,Class$；

I_c: The set of experimental courses belong to class c, $c = 1,2,\ldots,Class$；

J:The number of laboratories，   indexed by $j=1,2,\ldots,J$；

W: The number of weeks in a semester，   indexed by $w = 1,2,\ldots,W$；

D: The number of days that an experiment course can be scheduled in one week，   indexed by $d = 1,2,\ldots,D$；

H: The number of the total days which can be scheduled experiment courses in a semester，   indexed by $h = 1,2,\ldots,H$, $H = W * D$；

A: The number of experiment courses that can be scheduled in a day，   indexed by $a = 1,2,\ldots,A$；

K:The number of class session in a semester of one laboratory，   indexed by $k = 1,2,\ldots,K, k = 25 * (w-1) + 5 * (d-1) + a$；

K_w : The set of session belong to week w, $w = 1,2,\ldots,W$；

t_i:The start week of experiment course i；

du_i:The total weeks of experiment course i；

Num_i: the total number of the experiment course i；

C_j: the number of machines available in laboratory j；

decision variables

x_{ijk}: decision variable,$x_{ijk} = 1$ if the class i be scheduled in laboratory j during period k， 0 otherwise；

y_{ih} : decision variable, $y_{ih} = 1$ if class i be scheduled on day h , 0 otherwise

z_{iw} : decision variable, $z_{iw} = 1$ if class i be scheduled on week w , 0 otherwise

b_{ij} : decision variable, $b_{ij} = 1$ if class i be scheduled in laboratory j, 0 otherwise

The model of experimental courses scheduling is as follows:

$$\min \sum_{h=1}^{H} \min\left(1, \sum_{i=1}^{I} y_{ih}\right) \quad (1)$$

Subject to:

$$\forall i \in I, k \in K, \sum_{j=1}^{J} x_{ijk} \leq 1 \qquad (2)$$

$$\forall j \in J, k \in K, \sum_{i=1}^{I} x_{ijk} \leq 1 \qquad (3)$$

$$\forall i \in I, \sum_{w=1}^{t_i} z_{iw} = 0 \qquad (4)$$

$$\forall i \in I, \forall w \in W, \sum_{w=t_i}^{W} z_{iw} = du_i \qquad (5)$$

$$\forall i, i' \in I_s, i' \neq i, k \in K,$$

$$\sum_{j=1}^{J} x_{ijk} + \sum_{j=1}^{J} x_{i'jk} \leq 1 \qquad (6)$$

$$\forall i, i' \in I_c, i' \neq i, k \in K,$$

$$\sum_{j=1}^{J} x_{ijk} + \sum_{j=1}^{J} x_{i'jk} \leq 1 \qquad (7)$$

$$\forall i \in I, k \in K, Num_i * x_{ijk} \leq C_j \qquad (8)$$

$$\forall i \in I, j \in J, k \in K,$$

$$\sum_{n=1}^{du_i-1} x_{ij(k+25n)} * (\sum_{n=1}^{du_i-1} x_{ij(k+25n)} - du_i) = 0 \qquad (9)$$

$$\forall i \in I, \forall j \in J, \sum_{k=1}^{K} x_{ijk} = b_{ij} * du_i \qquad (10)$$

$$k = 25(w-1) + 5(d-1) + a \qquad (11)$$

$$k = 5(h-1) + a \qquad (12)$$

$$\forall i \in I, j \in J, k \in K, x_{ijk} = 0 \ or \ 1 \qquad (13)$$

$$\forall i \in I, h \in H, y_{ih} = 0 \ or \ 1 \qquad (14)$$

$$\forall i \in I, \forall w \in W, z_{iw} = 0 \ or \ 1 \qquad (15)$$

The objective function in (1) is to minimize the total number of days which scheduled the experimental courses. Constraint (2) limits that the same class cannot arrange two courses in the same period of time. Constraint (3) enforces that a laboratory cannot schedule two courses in the same time period. Constraint (4) guarantees each experimental course is scheduled after the earliest allowed start time. Constraint (5) guarantees that each experimental course is arranged according to the number of times required. Constraint (6) guarantees that the same teacher cannot schedule two courses in the same time period. Constraint (7) guarantees that the same class cannot participate two courses in the same time period. Constraint (8) limits that the number of machines available in the laboratory must be equal to or exceed the course's enrollment. Constraints (9) guarantees the same course is scheduled on the same day in a week and at the same session in a day. Constraints (10) guarantees the same course is scheduled in the same laboratory. Constraints (11)-(12) means the equations that are satisfied between the session number and the number of days, weeks, and sessions of the course. Constraint (13)-(15) constraint the decision variable 0-1 variable.

4. Numerical example

In this example, we will consider 4 laboratories and 18 weeks can be arranged for experimental classes in a semester. There are 5 days of experimental classes per week and up to 5 sessions per day.

Table 1. Laboratory information

Index	Laboratory	Capacity
1	10-B301	65
2	10-B302	65

| 3 | 10-B303 | 65 |
| 4 | 10-B304 | 65 |

Table 2. Class time information at the first week

	Monday	Tuesday	Wednesday	Thursday	Friday
1-2	$k=1$	$k=6$	$k=11$	$k=16$	$k=21$
3-4	$k=2$	$k=7$	$k=12$	$k=17$	$k=22$
5-6	$k=3$	$k=8$	$k=13$	$k=18$	$k=23$
7-8	$k=4$	$k=9$	$k=14$	$k=19$	$k=24$
9-10	$k=5$	$k=10$	$k=15$	$k=20$	$k=25$

Table 3. Courses' information waiting to be scheduled

Index	name	size	Start week	Teacher	weeks
1	...	150	2	S1	5
2	...	160	2	S2	11
3	...	130	3	S3	4
4	...	140	6	S4	10

5. Results

The model is solved by CPLEX. Due to the large number of courses in one semester, it is not convenient to show the results of all the experimental classes in one semester. So we show parts of the results in Table 4 and Figure 1.

Table 4. Scheduled results

Course Index	Lab Index	Lab capacity	Week Number	session
30022	10-B301	60	10	229
30022	10-B301	60	11	254
30022	10-B301	60	12	279
30022	10-B301	60	13	304
30022	10-B301	60	14	329
...	...	...	...	...
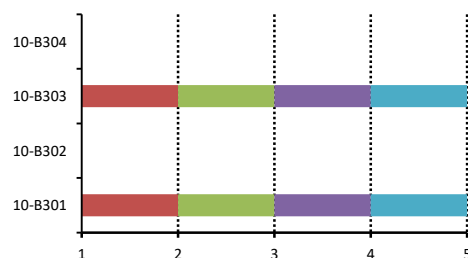
Figure 1. Results of course scheduling for the 16th week

The results show that the course which index number is 30022 is scheduled in 10-B301, and the sessions are 229, 254, 279, 304 and 329. According to the logical relationship in Table 2, session 229, 254, 279, 304 and 329 are all correspond to the fourth class on Monday. So the results satisfy that the

same course is scheduled in the same laboratory on the same day in a week and at the same time period in a day. And as you can see from figure 1, it is possible to implement centralized experimental courses scheduling

6. Conclusions

This paper presents a mathematical model of course scheduling problem and uses CPLEX to solve it. So we can solve the experimental courses scheduling problem by design an information system and improves the efficiency of course scheduling. Based on the analysis of the requirements of the experimental course scheduling system, this paper puts forward a mathematical model to solve the problem of course scheduling and chooses the methods and the tools needed to solve the problem, which provides the technical guarantee for the next development of the course scheduling system.

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