A Classroom Assignment Problem in University Term Examinations

Takeshi Koide
Department of Intelligence and Informatics
Konan University, Kobe, Japan
Tel: (+81) 78-435-2532, Email: koide@konan-u.ac.jp

Yumiko Naba
Department of Intelligence and Informatics
Konan University, Kobe, Japan
Tel: (+81) 78-435-2532, Email: s1371081@s.konan-u.ac.jp

Abstract. The university term examinations require several decision-makings such as timetabling, classroom assignment, and proctor assignment. This study focuses on the classroom assignment in our university. The classroom assignment task is manually conducted by university staffs and it needs more than three days. This paper proposes an optimization model for the classroom assignment problem and introduces a method to practice the model to actual assignment task. This study also developed a system in order to evaluate the usefulness of the optimization model by using practical numerical studies.

Keywords: classroom assignment problem, combinatorial optimization, operations research, practical study

1. INTRODUCTION

Optimization technique is advancing on a daily basis and it is widely utilized for many industries, even in educational institutions. Some studies focused on optimization in universities and timetabling is one of the hottest topic in optimization in universities (Abdullah and Alzaqebah, 2013; Ahandani et al., 2012; Azumi, 2005; Petrovic et al., 2007; Pillay and Banzhaf, 2009). The classroom assignment is one of a key component of the exam timetabling and Elloumi et al. (2014) discussed a classroom assignment problem critically to show its complexity and to propose some heuristics for the problem.

This paper also discusses the classroom assignment problem aiming to apply an optimization technique to a practical classroom assignment task in universities. This study adopted a similar mathematical optimization model to that in Elloumi et al. (2014), proposed a method how to practice the model to the actual assignment task, and developed a system which solved the optimization problem to derive classroom assignments. The performance of the approach was evaluated through numerical studies by using practical data in latest semester.

2. CLSSROOM ASSIGNMENT TASK

Our university, Konan University, adopts a two-semester system and implements exams at the end of the semesters. As a preparation for the exams, the registrar section conducts an assignment task of classrooms for all exams. The exams are conducted for around ten days and each of exam days has six periods. The number of exams is around 900. The number of target classrooms for the exams is round 70 among all 94 classrooms, which means that more than 20 classrooms are outside the scope in the exam period because of their structural features such as computer suite, multimedia rooms, and experimental laboratories.

The classroom assignment task is required because of the difference between capacities of classrooms in the regular school period and in the exam period. Exam takers sit a seat apart from each other in the exam period and the classroom capacity in the exam period is smaller than that in the regular period. The courses regularly conducted in classrooms unsuitable for exams also require other classrooms for their exams. Some faculties request to assign another classroom other than the classroom where they regularly give a lecture.

The absorption rate for a classroom assignment is defined as the rate of the number of examinee to the capacity of the assigned classroom. Higher absorption rate is desirable but assignments with 100% absorption rate are not welcome in case anything goes wrong on classroom facilities.

Classrooms themselves have their own priority to be assigned. The classrooms in buildings closer to the register section have higher priority since the exam headquarter is settled in the registrar section and it is easier for university staffs to deal with some troubles in closer classrooms. For a similar reason, classrooms in lower floors in a building have higher priority than those in higher floors because of their accessibility.

The classroom where classes in a course are given in the regular period are named the regular classroom for the course. A regular classroom of a course has an additional priority for the course since it is familiar for the faculty in charge of the course to reach the classroom. The familiarity with a classroom reduces troubles in the exam period. When a regular classroom cannot be utilized in the exam period, closer classrooms to the registrar section are desirable, especially for part-time faculties unfamiliar with the building placement in university campus.

Multiple classrooms are sometimes assigned to an exam such as the exams which have more examinee than the capacity of the largest classroom. In the case of the multiple classrooms assignments, the multiple classrooms should be closer to each other on the same floor in the same building. The examinee are divided into multiple groups and assigned to respective classrooms. The absorption rates are also evaluated for respective classrooms.

The staffs in the registrar section conduct the classroom assignment with considering the above-mentioned conditions. It takes around four days to accomplish the assignment by two or more staffs.

3. PRESENT DATA ANALYSIS

We conducted present a data analysis for the classroom assignment in our university in order to reduce the size of target problem. The practical data in fall semester in 2015-2016 academic year was targeted, where there were totally 853 exams for nine exam days. In-depth interviews with staffs in the registrar section were conducted several times in order to extract conditions considered and emphasized in the assignment task from the knowledge of the staffs.

In order to reduce the size of target problem, we proposed an approach to segment the classroom assignments into two groups. The assignments in the first group are conducted based on some heuristics in the preprocessing stage. The other assignments are determined by using optimization approach.

In the target semester, 66 classrooms were utilized to be assigned as exam classrooms. The analysis investigated and found that 16 classrooms were not intrinsically suitable for exams but sometimes assigned as a regular classroom. Such a classroom is named type-R classrooms in this study. The type-R classrooms are, for instance, small language classrooms or those with unique layout of seats. The optimization should focus on only 50 classrooms other than type-R classrooms.

The analysis also found that there were some conditions with respect to the decision if the assignments to regular classrooms should be appropriate:

A. the exam with a request from the faculty in charge to assign its regular room,
B1. the exam without any request from the faculty in charge,
B2. the number of examinee is not more than the exam capacity of a regular room,
B3. the exams whose regular class is a type-R classroom.

The exam with condition A is surely assigned to its regular classroom. If all conditions B1, B2, and B3 hold, a corresponding exam is assigned to its regular classroom. The judgement for assignments to regular classrooms is conducted in preprocessing stage and 376 exams were assigned to their regular classrooms in the target data. The other 477 classrooms led to the target of the optimization.

The analysis ascertained that the assignments in a period are independent of those in other period. It means that the target classroom assignment task can be divided into small tasks for respective periods. The optimization for the classroom assignment should be executed in 49 times for 49 periods. The average and the standard deviation of the number of exams in a period are 17.4 and 10.5, respectively.

The actual situation of the assignments to multiple classrooms were also investigated and found that groups of classrooms for the multiple classroom assignment were limited and could be enumerated regardless of the results of the assignments. This study proposed a virtual type of classrooms, named united classrooms, as the union of multiple classrooms. The optimization can assign a united classroom to an exam, which means that the multiple classrooms in the united classroom are assigned to the exam.

The interview was focused on the most important factors to determine which classroom is desirable for the target exam. Though the verification of many actual results of assignments, the following three are listed as the most important factors:

(a) absorption rate,
(b) priority of classrooms,
(c) regular classroom.

With respect to factor (a), the most desirable absorption rate should be 90% and the assignment with more than 90% absorption rate should be avoided.

The three factors sometimes mutually irreconcilable, it is quite hard to find a good setting for the three factors to derive convincing results. In order to assess the three factors simultaneously, we proposed to construct a value for assignments of a classroom to an exam considering the three factors. By the proposal, the target classroom assignment problem is modeled as the optimization problem to maximize the sum of values by the assignments with satisfying some given conditions. The concrete procedure to compute the values of assignments are explained in the following section.

4. MATHEMATICAL MODEL

This section explains the mathematical model for the target classroom assignment problem.

4.1 Optimization Model

This subsection defines optimization model utilized in this study. Firstly, sets, constants, and design variables in the optimization model are defined.

Sets:

- $\boldsymbol{I}$ index set for exams
- $\boldsymbol{J}$ index set for classrooms, including single and united classrooms
- $\boldsymbol{J_S}$ index set for single classrooms
- $\boldsymbol{J}_j$ index set consisting of a single classroom j itself and united classrooms containing the single classroom j

Constants:

- v_{ij} value for the assignment of classroom j to exam i
- δ_{ij} availability of the assignment of classroom j to exam i; 1 if the assignment is available, otherwise 0
- n_i number of the examinee for exam i
- c_j capacity of classroom j in the exam period

Design Variables:

- x_{ij} 1 if classroom j is assigned to exam i, otherwise 0

The classroom assignment problem is expressed the following optimization model, named CAP:

Problem CAP:

Maximize $$\sum_{i \in \boldsymbol{I}} \sum_{j \in \boldsymbol{J}} v_{ij} x_{ij} \quad (1)$$

Subject to:

$$\sum_{j \in \boldsymbol{J}} x_{ij} = 1, \quad \forall i \in \boldsymbol{I} \quad (2)$$

$$\sum_{i \in I} \sum_{k \in \boldsymbol{J}_j} x_{ik} \leq 1, \quad \forall j \in \boldsymbol{J_S} \quad (3)$$

$$x_{ij} \leq \delta_{ij}, \quad \forall i \in \boldsymbol{I}, \forall j \in \boldsymbol{J} \quad (4)$$

$$x_{ij} = 0 \;\; or \;\; 1, \quad \forall i \in \boldsymbol{I}, \forall j \in \boldsymbol{J} \quad (5)$$

The objective function, equation (1), in the optimization model implies to maximize the sum of values for determined assignments. The value v_{ij} of the assignment of classroom j to exam i is explained in the next subsection in detail.

The constraint (2) expresses that exactly one classroom has to be assigned to any exam i. The constraint (3) implies that any single classroom j must not be assigned to more than one exam. Note that the single classroom j itself is a member of the index set $\boldsymbol{J}_j$. The constraint (4) sets the variable x_{ij} to 0 if δ_{ij} is equal to 0, namely classroom j cannot be assigned to exam i. The binary condition for the design variable x_{ij} is given by the constraint (5).

4.2 Constants Settings

This subsection explains how to set the value of the constants in the optimization model defined in the previous subsection.

The constant δ_{ij}, a binary constant, has 1 if classroom j can be assigned to exam i, otherwise 0. In this model, the absorption rate n_i / c_j is not more than a given maximum absorption rate $r_{\max}$:

$$\delta_{ij} = \begin{cases} 1, & \text{if } n_i/c_j \leq r_{\max}, \\ 0, & \text{otherwise.} \end{cases} \quad (6)$$

The constants v_{ij} for the value of an assignment is computed by the following equations (7) through (9) considering the three factors described in the previous section:

$$v_{ij} = 100\frac{n_i}{c_j} + \alpha_{ij} + \beta_{ij} \quad (7)$$

$$\alpha_{ij} = \begin{cases} \alpha_{j\mathrm{F}}, & \text{if exam } i \text{ is charged} \\ & \quad \text{by a fulltime faculty} \\ \alpha_{j\mathrm{P}}, & \text{if exam } i \text{ is charged} \\ & \quad \text{by a parttime falucty} \end{cases} \quad (8)$$

$$\beta_{ij} = \begin{cases} \beta, & \text{if classroom } j \text{ is the regular} \\ & \text{classroom of exam } i \\ 0, & \text{otherwise} \end{cases} \quad (9)$$

The first term in the right-hand side of equation (7) means the absorption rate in percentage figure. The 1% increment of absorption rate increases the value of v_{ij} by 1.

The constant α_{ij}, defined in equation (8), indicates the priority of classroom j if it is assigned to exam i. The classroom with higher priority has higher value of α_{ij}. The value α_{ij} depends on the property of the faculty in charge of the exam i, and the value varies with whether the faculty is full-time or part-time. In equation (8), $\alpha_{j\mathrm{F}}$ and $\alpha_{j\mathrm{P}}$ are positive values and they express the priorities of classroom j for the exam charged by full-time faculties and part-time faculties, respectively.

The constant β_{ij} in equation (7) is for the regular classroom assignment. If assigned classroom j is the regular classroom for exam i, the value of assignment is increased by a constant positive value β.

The values of the above-mentioned constants, such as $\alpha_{j\mathrm{F}}$, $\alpha_{j\mathrm{P}}$, and β, were set manually through a trial and error process to make resulting assignments conformable to the assignments by registrar section staffs.

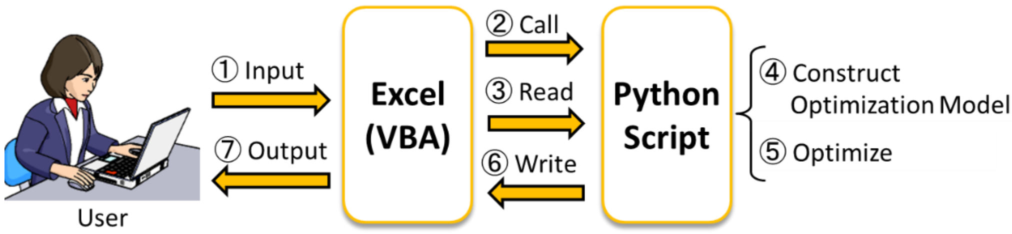

Figure 1: Process flow diagram for developed system.

5. IMPLEMENTATION

In order to evaluate the usefulness of the proposed method for the classroom assignment task, a system was developed to derive assignments based on the proposed approach. The process flow of the system is illustrated in Figure 1. The system adopts Microsoft Excel as the user interface and users inputs the required data into a spreadsheet in the system. The required data with respect to exams are the name or the code of courses, the number of examinee n_i, the date and the period of exams, the regular classroom, and the position of the faculty in charge.

The information for classrooms are basically inputted in the system and can be modified by users. The required data

Table 1: A summary of target data

number of days	9
max. number of periods per day	7
total number of periods	48
number of exams	909
number of single classrooms	93
average of the number of exams per period	18.9
s. d. of the number of exams per period	11.2

with respect to classrooms are the capacity c_j, the priorities for full-time and part-time faculties α_{jF} and α_{jP}, respectively, and the classroom type. The classroom type is single or united and the united classrooms are further required their composition $\boldsymbol{J}_j$.

In order to execute the optimization, the values of some parameters for assignment value v_{ij} are also needed, such as the maximum limit of the absorption rate $r_{\max}$, and the additional priority for assignments to regular classrooms β.

After inputting the above-mentioned required information, users just click a button to make assignment. The system calls a Python script by Excel VBA. The Python script reads essential data from the spreadsheet to construct an optimization model for CAP shown in the previous section. The problem is solved by using an imported external optimization solver and Gurobi Optimizer is utilized in this study. The resulting optimum solution is converted in the form of optimum assignment and outputted to a spreadsheet in the system.

6. ASSESSMENT AND EXTENSIONS

6.1 Performance Assessment

The performance of the proposed method was assessed by using practical data for the spring semester in 2016. The summary of the practical data is shown in Table 1. The executional time of the optimization for each period took less than one second.

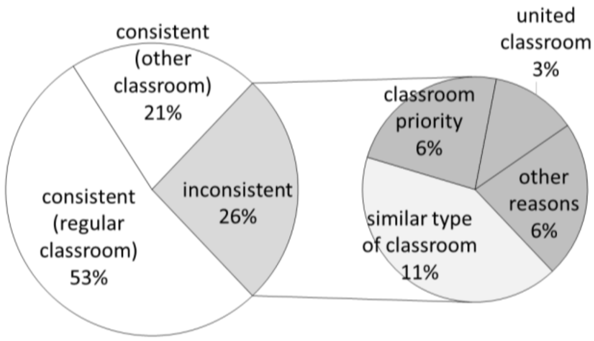

Figure 2: Consistency of assignments

The resulting assignments were compared with the assignment made by staffs in the registrar section and both their differences and the causes for the differences were scrutinized. The results are summarized in Figure 2. The system assigned the identical classroom for 74% of exams, where 53% of exams are assigned to their regular classrooms. The inconsistent assignments occupy 26% and 11% of assignments are practically regarded as almost consistent. In other words, the system assigned another classroom with the same classroom features as those the staffs in the registrar section assigned. The other assignments are indeed inconsistent and the most of inconsistency was occurred by scoring both the priority of classrooms and united classrooms.

6.2 Modifications and Extensions

After the performance assessment of the method, additional interview was conducted to the staffs in the registrar section in order to pursue the causes of the inconsistency. As a result, some new requirements were extracted for the assignment task.

- There is a small difference of priority among classrooms on the same floor in the same building. The classroom closer to an elevator has slightly higher priority.
- The maximum limit $r_{\max}$ can be relaxed when the assignment is synthetically excellent.
- Excessively low absorption rate is also undesirable. The value function with respect to the absorption rate should not be simply linear but piecewise linear or concave.

The new requirements can be incorporated just by modifying equation (7) for the assignment value v_{ij} and the proposed optimization model must not be modified.

7. CONCLUSIONS AND FUTURE WORKS

This study proposed an optimization model for classroom assignment task in a university. A present data analysis was conducted and a method to determine the values of constants in the optimization model was proposed. The quality of the derived assignments by the proposed method was evaluated with using practical data and the method was shown to be helpful for the staffs in the registrar section. The evaluation of derived assignments by the proposed method will be continued to improve the quality of the resulting assignment.

In this study, the proposed optimization model ignores how to make groups of examinees for assignments to united classrooms. In the practical assignment task, the staffs take examinee's properties into account in order to split examinee into multiple single classrooms. An optimization model for the split of examinee will be discussed in the forthcoming paper.

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