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Improvements on Spreadsheet-Based System for Seminar Assignment Problem with Rotations

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Abstract— **In author's department, a preliminary seminar is offered to junior students. The students are assigned to three different laboratories to experience research activities in the course. The assignment is accomplished by a faculty member in the department with considering both student's preference on laboratories and some conditions on laboratories. A prototype spreadsheet-based system for the assignment operation was developed in my previous research. The assignment was formulated as a mixed integer programing and the system derived an optimal solution of the optimization problem. The quality of the derived results is acceptable for practical use but some constraints were newly revealed through the trials of the system. This paper summarizes past achievements and proposes some improvements on the developed formulation. The improved system demonstrates appropriate performance for practical use.**

Index Terms—**mixed integer programming, optimization, seminar assignment, spreadsheet**

I. Introduction

A preliminary seminar, named pre-semi, is a course in author's department where third-year students go through introductory research activities. The corresponding semester consists of fifteen weeks and it is divided into three cycles, namely five weeks for each cycle. The students experience three different types of researches in each cycle and the assignment of students to slots, the pairs of a laboratory and a cycle, are determined before pre-semi starts. The assignment operation is conducted by a faculty by rotation among faculty members in the department. The operation is complex for most faculties and it needs more than several hours to accomplish the assignment.

In author's previous work [1], a spreadsheet-based system was developed to achieve the pre-semi assignment operation. The pre-semi assignment is a type of laboratory assignment problems, mentioned in detail in [2]. The existence of the rotation of students in each cycle is the major difference in pre-semi assignment compared to general laboratory assignment problems. Kuwano proposed a mathematical formulation for laboratory assignment with rotations as a optimization problem. The author modified Kuwano's model to deal with the pre-semi assignment and an optimal solution was explored by using external commercial optimization software [4]. The optimization finished in substantially shorter time than the traditional manual operation and the quality of resulting output was basically satisfactory. Through the reviews by department faculties, however, some considerable conditions have been newly excavated.

In this paper, some improvements on the developed system are proposed to tackle the revealed new conditions. The improvements contribute to a practical application of the system. Section II summarizes the practical pre-semi assignment operation. Section III constructs a mathematical model for the assignment and the system development is mentioned in Section IV. Section V shows the results of numerical experiments and discusses practicality of the system and Section VI concludes the paper.

II. Pre-semi Assignment Operation

First, faculty members post the syllabus of pre-semi which contains the content of research activity and the capacity of his/her laboratory. Prospective pre-semi students, then, are supposed to read the syllabus and to submit questionnaires where they handle their priorities for laboratories.

Next, a faculty member starts to assign students to slots, defined as the pair of a laboratory and a cycle. The constraints and the goals of the assignment are shown as follows:

[Constraints]

(c1) Students must be assigned to three different laboratories.

(c2) Students must be assigned to a laboratory in each cycle.

(c3) Reverse assignments are prohibited. The reverse assignment is the assignment where a student A is not assigned to a laboratory B but another student whose preference to the laboratory B is lower than that of the student A is assigned to the laboratory B unless the student A is assigned three laboratories with higher preference than laboratory B.

(c4) The number of assigned students to laboratories must not exceed the capacity of laboratories in any cycles.

[goals]

(g1) Students should be assigned to laboratories with their higher preferences.

(g2) The number of open slots should be reduced. The open slot is defined as the slot to which at least one student is assigned. On the contrary, the slots without assigned students are referred to as closed slots.

(g3) The number of assigned students to open slots of a laboratory should be equalized.

In the case of the manual assignment, the assignments of students to laboratories are initially determined with considering constraints c1, c2, c3 and goal g3. Then the assignments of students to cycles are examined to improve the remaining goals with considering constraint c4.

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III. Mathematical Modeling

A. Nomenclature

This subsection defines the variables, constants and sets utilized in the proposed mathematical model.

Sets

- I index set for students to be assigned
- J index set for laboratories
- K index set for cycles
- L index set for student's preference
- Ω set of student-laboratory pairs
- Ω_0 subset of Ω with $f_{ij} = 0$
- Ω_1 subset of Ω with $f_{ij} = 1$

Constants:

- a_{ij} satisfaction level by the assignment of student i to laboratory j
- c_j capacity of laboratory j
- f_{ij} 1/0 if student i is fixed to/not to be assigned to laboratory j before the assignment planning, –1 otherwise
- r_{ij} preference ranking order of student i to laboratory j
- w_h weight in the objective function ($h = 1, \ldots, 3$)

Decision Variables:

- x_{ijk} 1 if student i is assigned to laboratory j in the k-th cycle, 0 otherwise
- y_{jk} 1 if a student is assigned to laboratory j in the k-th cycle, 0 otherwise
- z_j positive minimum among the numbers of assigned students to laboratory j in each cycle
- s_{il} 1 if student i is assigned to his/her l-th preferred laboratory, 0 otherwise
- $\bar{s}_{il}$ 1 if student i is assigned to three laboratories for which his/her preferences are higher (smaller ranking order) than l, 0 otherwise

B. Formulation

By using the variables and sets defined in the last subsection, the pre-semi assignment is formulated as an optimization problem, named Problem MP, as follows:

Problem MP:

Maximize $\quad w_1 f_1 - w_2 f_2 + w_3 f_3 \quad (1)$

subject to

$$f_1 = \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} a_{ij}\, x_{ijk}, \quad (2)$$

$$f_2 = \sum_{j \in J} \sum_{k \in K} y_{jk}, \quad (3)$$

$$f_3 = \sum_{j \in J} z_j, \quad (4)$$

$$\sum_{k \in K} x_{ijk} = 1, \quad i \in I, j \in J, (i,j) \in \Omega_1 \quad (5)$$

$$\sum_{k \in K} x_{ijk} = 0, \quad i \in I, j \in J, (i,j) \in \Omega_0 \quad (6)$$

$$\sum_{k \in K} x_{ijk} \le 1, \quad i \in I, j \in J, (i,j) \in \Omega \setminus \Omega_1 \setminus \Omega_1 \quad (7)$$

$$\sum_{j \in J} x_{ijk} = 1, \quad i \in I, k \in K \quad (8)$$

$$z_j - c_j(1 - y_{jk}) \le \sum_{i \in I} x_{ijk} \le c_j y_{jk}, \quad j \in J, k \in K \quad (9)$$

$$s_{il} = \sum_{k \in K} x_{i r_{il} k}, \quad i \in I, l \in L \quad (10)$$

$$\bar{s}_{il} = 0, \quad i \in I, l = 1,2,\ldots,|K| \quad (11)$$

$$|K| \bar{s}_{il} \le \sum_{l'=1}^{l-1} s_{il'}, \quad i \in I, l = |K|+1, \ldots, L \quad (12)$$

$$\sum_{k \in K} x_{i r_{i_1 l_1} k} + \bar{s}_{i_1 l} \ge \sum_{k \in K} x_{i r_{i_2 l_2} k}, \quad i_1, i_2 \in I, l_1, l_2 \in L, l_1 < l_2, r_{i_1 l_1} = r_{i_2 l_2} \quad (13)$$

$$x_{ijk}, y_{jk}, s_{il}, \bar{s}_{il} \in \{0,1\}, \quad i \in I, j \in J, k \in K, l \in L \quad (14)$$

$$z_j \ge 0. \quad j \in J \quad (15)$$

The objective function (1) in Problem MP consists of three measurements f_1, f_2, and f_3 defined by (2) through (4).

The developed system is based on Microsoft Excel, spreadsheet software. The required data for Problem MP are inputted into spreadsheets and Problem MP is then solved by CPLEX [4], commercial optimization software.

In the previous work [1], equations (10) through (13) were not considered and the system was expected to avoid the reverse assignment by appropriate settings of variables a_{ij}, satisfaction level of assignments. The expected method was useful in most cases but did not guarantee against the prohibition of the reverse assignment.

IV. Numerical Results and Discussion

Numerical experiments have been conducted using actual past data for the pre-semi assignment operation. The data include 141 students, 19 laboratories, 3 cycles, and 11 preferences, namely $|I| = 141$, $|J| = 19$, $|K| = 3$, and $|L| = 11$. The satisfactory level a_{ij} for assignment of student i to laboratory j is determined by the next equation:

$$a_{ijk} = \begin{cases} 2^{L - r_{ij}} & \text{if } r_{ij} \le L, \\ 0 & \text{otherwise.} \end{cases} \quad (16)$$

All of the values of f_{ij}, are set to 0, which means that no assignments are predetermined. The numerical experiments are conducted using a PC with Intel Core i5-2400 (3.1GHz) CPU, 4GB memory, Windows 7 (64bit). The versions of Excel and CPLEX are 2010 and 12.2, respectively.

In the following subsections, sensitivity analysis has been conducted on the values of weights in the objective function.

A. Weight on Number of Open Slots

The weight w_2 on the number of open slots is focused in this subsection. The other weights are set as $w_1 = 1$ and $w_3 = 0$. Greater value of w_2 implies that the reduction of the number of open slots is relatively emphasized against student's satisfaction.

Table I summarizes the numerical results for various values of weight w_2. The value of f_2, the number of open slots, decreases with respect to w_2. The value of f_3, the sum of the estimates on equal assignments for laboratories, is also improved by increasing of w_2. Decreasing the number of open slots increases the number of students in open slots and it indirectly improves the value of f_3.

The increase of the number of assigned students among cycles is generally achieved by the deterioration of student's satisfaction. Table I, however, shows that the worst assigned

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TABLE I
COMPUTATIONAL RESULT FOR VARIOUS VALUES OF WEIGHTS w_2

weight w_2	0	1	5	20	40
value of f_2	56	44	42	41	40
rate of open slots	98.2%	77.2%	73.7%	71.9%	70.2%
value of f_3	121	163	174	181	188
worst assigned preference	7	7	7	7	8
value of f_1	240,800	240,800	240,800	240,800	240,792
computational time (sec)	6.6	8.9	11.2	17.4	52.4

TABLE II
COMPUTATIONAL RESULT FOR VARIOUS VALUES OF WEIGHTS w_3

weight w_3	0	1	2	5	10
value of f_2	56	42	41	40	40
rate of open slots	98.2%	73.7%	71.9%	70.2%	70.2%
value of f_3	121	180	184	193	193
worst assigned preference	7	7	7	8	8
value of f_1	240,800	240,800	240,800	240,792	240,792
computational time (sec)	6.6	24.1	61.4	122.1	408.9

preference of students and the value of f_1 retains the same value for $w_2 = 0$ through 20. In the case of $w_2 = 40$, the two estimation measures are declined. The best quality of assignment in Table I is derived by the setting $w_2 = 20$ because it minimized the number of open slots with keeping the worst assignment preference of students. Computational time also increases with respect to w_2.

B. Weight on Score for Equal Assignment

Table II displays the results for various value of w_3, the weight on the sum of estimates on equal assignment for laboratories, with $w_1 = 1$ and $w_2 = 0$. Similarly to Table I, increasing of the value of w_3 improves the estimates on the number of assigned students, deteriorates student's satisfaction, and requires more computational time.

In Table II, the weight $w_2 = 2$ derives the best quality because it results in the minimum open slots and the maximum score of f_3 with keeping worst assigned preference level.

In both tables, all of values of f_1 are the same 240,800 for all cases when the worst assigned preference is 7 in spite of the change of the values of f_2 and f_3. This is because the assignment of students to laboratories is not changed but the assignment of students to cycle is changed.

In all of experiments, reverse assignments are never occurred thanks to the explicit formulation given by (10) through (13). The new formulation requires more computational time compared with the previous model in [1].

IV. CONCLUSION

This paper proposed an improvement on a spreadsheet-based system for pre-semi assignment operations. The proposed mathematical model considers the prohibition of the reverse assignment implicitly. Numerical experiments confirmed that the improvement has been surely conducted and showed that the weight w_3 on the score for equal assignment is more efficient to derive practical results than the weight w_2 on the number of open slots.

As future works, an extension of the proposed optimization to a two-stage optimization shows much promise. In the first step, a minimization of the worst assigned preference is derived under satisfying required constraints. In the second step, an optimization on both student's satisfaction and balanced assignment is executed. The derived minimum worst assigned preference enables to ignore student's lower preference than the worst, to decrease the size of the optimization model, and to save computational time for the optimization. The resulting estimate on the weights of the objective function in the numerical study would be useful in the second step.

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