An Approach to Rational Class Organization Methods
in Elective Subjects-based Curricula

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Abstract
This paper proposes an effective lecture allocation method based on users' profiles and utilities in elective subjects. In many universities and colleges, elective subjects systems are employed as a curriculum in which students make their own learning experiences. Students select multiple subjects based on their interests and preferences. Generally, each university determines members of elective subjects based on only one simple rule, such as the order of grade, random selection, and first arrival. Current determination systems have strong limitations in terms of reflecting users' multiple preferences. We propose a new determination algorithm and a user support system based on users' profiles and multi attribute preferences. When users' preferences are not reflected in algorithm-based determination, a coordination agent decides lecture allocation cooperatively with each user's agent. Main advantage of our system is mainly that lectures are allocated effectively, that is reflected users' multiple preferences.

1 Introduction
As computer engineering develops, many systems have been proposed for supporting in education. In this paper, we propose a lecture allocation support system for elective subjects. Our system is a class organization support system to determine allocations of lectures that can be used in universities. In the universities, there are compulsory/required subjects and elective/optional subjects. Students take elective subjects selecting many options prepared by university.

In current class organization for elective subjects, managers/universities have a survey before opening a term in advance. The manager determines allocations of lectures based on rules and criteria. In general, there are some constraints and conditions, that is, capacities of classrooms/lecture rooms and number of students who take the lectures for each lecture. Students poll lectures they want to take before starting a term. When number of students is less than the capacity of lecture room for the lecture, all students are admitted taking and attend the lecture. On the other hand, when number of students is less than the capacity of lecture room for the lecture, manager decides class members based on a criteria such as orders of first poll, grade. Successful students can take and attend the lecture, however others must change lecture they take. Unsuccessful students' preferences are not reflected effectively in current class organization/lecture allocation methods, although the purpose of elective subjects is mainly self-coordination of curriculum through selecting lectures students want to take [2]. To solve the problem, we propose a class organization and lecture allocation support system based on users' multiple preferences [1][3]. First, lectures are allocated based on multiple purposes input by students. Second, when students' preferences are not reflected effectively, coordination agent sends confirmations to students and determines allocations of lectures cooperatively with students.

The reason why our system has two steps is as follows. First, when lectures in which a student does not want to take are allocated, the student sometimes denies attending such lectures. When the degree of importance among lectures in which the student polls as substitutes is too different, unsuccessful student may study by himself/herself but taking the lectures. As the result, when a school term opens, some lectures have vacancy seats. This situation is also not good conditions/situations for school managers. Second, when there are relationships of teaching contents/syllabus among multiple lectures, students sometimes want to take the lectures as a set, namely, some lectures are complementary for the students. In that case, when students cannot take all lectures they want to take, students may change a pattern of their self-coordinated curriculums. At least, the above situation can be observed in the universities where open elective subjects-based courses. Based on the above reason, our system has two steps, that is, computational allocations process and cooperative allocations process.

Advantages of our system can be described as follows.
First, students' preferences are reflected effectively. Second, lectures are allocated based on school managers' educational intentions. Finally, using our system, classes are organized cooperatively through negotiation between users and coordination agent. The contribution of this paper is in the integration of the theory, implementation and user perspectives.

There are some related works about class organization in universities, however they are not taking users' preferences into considerations[4]. Higaki proposed a registration system in which the system never stop even though many users use the system simultaneously. The system can run successfully, however basically the method of class organization is not novel and is trivial. Moreover, users' profiles are not referred to for lecture allocations in the existing work.

As the result, class are organized based on simple rules, which is decided by managers, without students' intentions.

The rest of the paper is organized as follows. Section 2 outlines of elective subjects. In Section 3, we propose a novel lecture allocation method and support system. In Section 4, we show a determination process through negotiation and present our system's user interface example. After that, in Section 5, we present a preliminary simulation and experiment using our method. Finally in Section 6, we provide some final remarks.

2 Class Organization in Elective Subjects

2.1 Elective Subjects

Elective subjects system in universities is an effective form of student-centered curriculum. In general, types of lectures are classified as compulsory curriculums-based lectures and elective/optional subjects-based lectures. Many universities in America and Japan employ the system and provide to students both multiple compulsory curriculum-based and elective subjects-based lectures. Basically, in America, many universities employ lectures/classes allocation based on a first arrival method as class organization/determination. First, students register classes/lectures they want to take. After the number of registration becomes equal to the number of seats the lecture take place in, students can not register to the lecture. On the other hand, in Japan, many universities employ lectures/classes allocation based on a grade-based or a random selection-based method as class organization/determination. Lectures are allocated the order based on students' grade, that is, higher grade. Lower grade students sometimes can not take a lectures. Otherwise, lectures/classes are allocated at random.

In general, most of students have multiple purposes and preferences when they select and take lectures from multiple elective subjects. However, in the above example, students' multiple purposes and preferences are not reflected effectively because classes are allocated without such students' intentions. These situations are problems because the purpose of elective subject system is realizing making original curriculum for each student. To solve the problems, we propose an effective lecture/class allocation method based on users' multiple preferences in elective subjects. Our system determines lectures/classes allocations base on users' multiple preferences and the students' histories of curriculum.

To clarify users' multiple preferences for lectures, we investigated the preferences through questionnaire. Table 1 shows a result of the investigation about selection criteria when students select and take lectures.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest</td>
<td>11</td>
</tr>
<tr>
<td>Difficulty</td>
<td>9</td>
</tr>
<tr>
<td>Time</td>
<td>7</td>
</tr>
<tr>
<td>Human Relations</td>
<td>6</td>
</tr>
<tr>
<td>For Qualification</td>
<td>3</td>
</tr>
</tbody>
</table>

As shown in the table, students have many attributes when they selects classes. Thus, in our paper, we propose the class organization method based on users mult attribute preferences. Furthermore, we use students profile data sets to recommend appropriate lectures.

2.2 Environments and Users Profiles

The lectures/classes allocation system reserves users profiles and their preferences based on the history of input contents by users and their curriculums. Classes' data and users' data are input to the database in advance. When users select and declare their preference to take classes before new term starts, the input data are reserved. Basically, all data sets consists of attributes shown in the Table 2 including lectures information. These attributes are necessary to be managed when the classes are allocated.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Data sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>Name, credit, teacher, date and time</td>
</tr>
<tr>
<td>Curriculum</td>
<td>Constraints, form(elective, compulsory), attributes</td>
</tr>
</tbody>
</table>
Students preferences are reserved as the data sets of each students’ profiles. Universities define the relationship between each class concerned with lectures profiles, such as science, language and so on. Furthermore, lectures profiles include the information about the learning level of subjects, learning areas and relationship among specializing research areas. These data are particularly used at the recommendation between agents and users. We propose class organization algorithm to determine classes/lectures allocation, however the allocation sometimes does not satisfied effectively. Then, a coordination agent, that is software, recommends lectures to users whose preferences are not reflected effectively. The agent recommends the lectures based on the data sets reserved in the user profile database. The detail of recommendation using the user profile data is shown at Section 4.

### 3 Class Organization Algorithm

#### 3.1 Model

In this section, we show definitions and assumptions for lecture allocations in our class organization method. The definitions are used in formalization of class organization algorithm. In the lecture allocations, we use the concept of utility as criteria to show students’ satisfactions [6][7]. When users preferences are reflected effectively, their utilities increase.

- **We assume a set of students** \( S = \{ s_1, s_2, ..., s_i, ..., s_n \} \). \( s_i \) is \( i \)th’s student.
- **A set of lectures is described as** \( A = \{ a_{1j}, a_{2j}, ..., a_{ij}, ..., a_{nj} \} \). \( a_{ij} \) is \( j \)th’s lecture. \( t_k \) shows day and time in which lecture \( k \) opens. \( t_k \in T. T \) is a set of day and time that lectures can be opened.
- **\( V_{ia}^{uk} \) is student \( i \)’s evaluation value for lecture \( k \).** \( 1 \leq i \leq n, 1 \leq k \leq m \). These evaluation values are shown as a set of multiple attributes and their values.
- **We assume that same multiple lectures are not held.**
- **A set of selection of lectures is defined as** \( G = \{ (G_1, ..., G_m) : G_i \subseteq A \} \). \( G_i \) is allocation to student \( i \).

In our system, students declare their multiple preferences for all lectures. We employ multi-attribute utility theory to show users’ multiple preferences. A utility function consists of multiple independent attributes based on MAUT (multi-Attribute Utility Theory) [5]. In general, MAUT handles problems for which outcomes are characterized by two or more attributes. For example, purchasing a new car requires consideration of the price, the shape, the color, the type, etc. In MAUT, for an alternative \( C_i \), the attributes \( X_1, X_2, ..., X_n \) exist, and their values are \( x_1(C_i), x_2(C_i), ..., x_n(C_i) \). We can represent the utility \( u(C_i) \) for the attribute \( C_i \) as

\[
u(C_i) = f(x_1(C_i), ..., f_n(x_n(C_i)))
\]

where \( f \) is a certain function. We can select several options with respect to \( f \), according to the application area. Based on the above utility, each agent has a preference, and according to von Neumann-Morgenstern, we define an agent’s preference as follows: \( C_i \succ C_j \iff u(C_i) > u(C_j) \) and \( C_i \sim C_j \iff u(C_i) = u(C_j) \). Here, \( C_i \succ C_j \) means that the agent prefers \( C_i \) to \( C_j \), whereas \( C_i \sim C_j \) means that the agent has no preference for \( C_i \) or \( C_j \). A user’s preference is quantified into a multi-attribute utility by using MAUT.

- **For lecture \( a_{ik} \), when the number of attribute is \( l, \) \( h \)th’s attribute valuation is shown as \( u_{ih}^{a_{ik}}. 1 \leq h \leq l. \)** We assume \( h \)th’s preference is shown as \( p_h \).
- **Student \( i \)’s synthesis valuation is shown as** \( V_i^{a_k} = f_i(u_{i1}^{a_k}, ..., u_{ih}^{a_k}, ..., u_{il}^{a_k}) \). Here, function \( f \) shows multi-attribute utility function. In this paper, we assume that \( f \) is multi-attribute linear utility function. Using the function, user’s valuation is shown as \( V_{ia}^{uk} = \sum_{h=1}^{l} u_{ih}^{a_{ik}} \).

Here, we consider about school manager’s educational intentions. Even though lectures are allocated based on students’ evaluation values, some allocations are not educational because students’ multiple preferences included non-educational attributes for students. Therefore, in our system, managers can decide the control values for the non-educational attributes.

- **In our system, school managers can decide utility function controlled influences of non-educational attribute values based on their educational intentions.** For example, when attribute \( H \) is not educational, controlled valuations are shown as \( c_{iH} \cdot V_{ia}^{uk} \), that is, multiplied values between student \( i \)’s evaluation value \( u_{ih}^{a_{ik}} \) and control value \( c_{h} \). Thus, student \( i \)’s synthetic evaluation value is modified as \( V_{ia}^{uk} = \sum_{h=1}^{l} u_{ih}^{a_{ik}} + c_{h} \cdot u_{ih}^{a_{ik}} \).
- **All students can not know the value \( c \) that is set up by school managers.**
- **Student \( i \)’s utility is defined as** \( u_{ia}^{uk} \) when the student take a lecture \( a_{ik} \). \( u_{ia}^{uk} \) can be described as satisfaction for lectures which is allocated.
- $V^{i}_{nk}$ is defined as evaluation values of lectures that is allocated to the student and student $i$’s utility $u^{i}_{a}$ is assumed as $V^{i}_{nk}$. Namely, $u^{i}_{a} = V^{i}_{nk}$.
- For student $i$, $u_{i} = \sum_{i=1}^{n} u^{i}_{a}$.
- All students’ total utilities $U$ is defined as sum of each student’s utility. Namely, $U = \sum_{i=1}^{n} u_{i}$.

To simply, we omit the description of modified evaluation values from the following section. Namely, we assume that all evaluation values have been modified based on school managers’ intentions.

3.2 Class Organization Algorithm

The optimal resolution of combination of lecture allocation is calculated based on total sum utility $U$ is maximum. Namely, such allocation is shown as $G = \text{argmax} \sum_{i=1}^{n} u_{i}$. In general, these problems about lecture allocation are NP hard problems. When number of students and multiple attributes increase, solution spaces are extended. We propose an algorithm for a lecture allocation using an empirical method. Advantages of our algorithm are that users’ preferences can be reflected. Here, we show the Class Organization Algorithm as follows.

[Step 1] Students select lectures/subjects they want to take. Student $i$ is input evaluation values $v^{i}_{nk}$ of lecture $a_{k}$. $V^{i}_{nk}$ is decided based on the above multi-attribute linear utility function.

[Step 2] Pre-allocation is computed, that is, students’ evaluation values are maximum. Namely, allocation is decided based on $\text{max}_{k} V^{i}_{nk}$.

[Step 3] Successful students in lecture allocation are decided based on constraints decided by managers in advance. Lectures are allocated based on the constraints and students’ evaluation values in large order valuation among students’ evaluation values.

[Step 4] Here, unsuccessful students are separated based on the following two conditions. First, simply, we assume evaluation value $V^{i}_{nk}$ is $k$th large order valuation for student $i$. Two sorts of conditions are given.

1. $V^{i}_{nk} - V^{i}_{nk-1} \leq q$
2. $V^{i}_{nk} - V^{i}_{nk-1} > q$

$q$ is a threshold value about compromise decided by school manager. Based on the above conditions, classes are organized as follows.

input: $V^{i}_{nk}, (1 \leq k \leq m)$,
output: Determination of allocation

procedure Determination

begin
$k = 2$
while $(k < m)$
if $a_{k}$ is available,
if $V^{i}_{nk} - V^{i}_{nk-1} < q$
then Lecture $a_{k}$ is allocated to the student.
else [step 5]
else $k++$
end

end

If the case is (1), lectures in which sorted valuation is second are allocated. When there are no vacancy seats of the lecture, allocation is determined based on the above algorithm. If the case is (2), [Step 5] is adopted.

[Step 5] Our system recommends substitute lectures to students. Based on answer from the students, lectures are allocated one after another.

4 Lecture Allocation Support System

4.1 Outline

Our system mainly consists of input interface module and utility calculation module and module for determination of lecture allocation. Constraints input by school managers are number of seats for each classroom, constraint values $c$ and threshold value $q$, etc. These are used in class organization in the calculation module. Based on students’ evaluation values, lectures are allocated using our algorithm.

Advantages of our system can be described as follows. First, students’ preferences are reflected effectively. Second, lectures are allocated based on school managers’ educational intentions. Finally, using our system, classes are organized cooperatively through negotiation between users and coordination agent.

4.2 Determination Process

Figure 1 shows the outline of determination process through negotiation between users and agent in our system. When a user’s utility is more than threshold value $q$, a lecture is allocated to the student. On the other hand, when a user’s utility is less than threshold value $q$, negotiation process starts. Coordination agent is implemented in our system and the agent computes users’ utilities and sends e-mail for confirmation to the students. First, coordination agent sends e-mail to inform reserved lectures to users. Second, students reply whether they accept substitute/reserved lectures or not. The deadline is set up by school managers. When students do not reply, agent regards that the students accept the agent’s suggestions.
4.2.1 Acceptance

Agent allocates lectures to the students who reply as acceptance when constraints are satisfied. When constraints are not satisfied, coordination agent re-sends confirmation and suggestion e-mail to students.

4.2.2 Rejection

When students declare rejection, coordination agent proposes and presents the other substitute lectures to the students. The above process continues until deadline decided by managers.

4.3 Interface Example

In this subsection, we show examples of user interface of our system. Figure 2 shows input interface for students.

Students select lectures based on their multiple preferences. First, students select lectures from the combo boxes which shows left in the Figure 2. Central combo boxes have a function in which students selects day and time the lectures are opened. This function is related with the combo boxes about lectures. When lectures are selected, day and time presents. Students decide multi attribute preferences’ values to select the radio button. When students fill out the form, they push send button. The data input by the students are reserved in the database file. After deadline of registration, our system computes users’ utilities in utility calculation module.

Figure 3 shows management interface for school managers. School managers can decide, change and adjust rules and methods of calculation. The “change weight” button in Figure 3 is used in adjustment of educational allocation for school manager. The part of “restriction area” is used in adjustment of constraint of situation/condition, that is, number of classroom, number of seats, and so on. When the “vote management” button is pushed, the condition of registration and credit records of students are displayed.

5 Experiments

5.1 Simulation

We conducted the simulation experiment, in order to show that our pre-allocated method is more effective than the existing method. First, it is assumed that the three numbers of lectures that can be selected. A student inputs multi attribute preferences about each lecture. The utility is calculated based on values input by the student. We used the protocol described above as the pre-allocation determination method. We assumed the following conditions. (1) 100 students can accommodate each classroom. (2) The number of total student is 300. In order to simplify, in this simulation experiment, we made the utility three stages of 0.1 and 0.2 and 0.3. The preference about each lecture of a student used the uniform distribution. Figure 4 is the graph shown the result of this simulation.

The determination based on vote ranking, determination based on the order of arrival, and determination based on the order of a grade” are methods used in current universities. The result of our simulation gives that students’ utilities are reflected effectively using our method comparing.
based on agent’s recommendations, users send their answer for each lecture.

\( s_2 \): reject, accept, reject
\( s_3 \): accept, reject, reject
\( s_7 \): reject, reject, accept
\( s_8 \): reject, accept, reject

As the result, \( a_{12} \) is allocated to user \( s_7 \). The number of lecture \( a_6 \)’s capacity is over by selection of users \( s_2, s_3 \) and \( s_8 \). Therefore, agent starts negotiation with the users again. Finally, \( s_2 \) selects \( a_6, s_3 \) selects \( a_{18} \), and \( s_8 \) selects \( a_{15} \) based on agent’s recommendation.

6 Conclusion

In this paper, we proposed a novel lecture allocation method based on users’ multiple preferences and their profiles data.

Our method realizes an effective allocation result in our experiments.

Advantages of our system can be described as follows. First, students’ preferences are reflected effectively. Second, lectures are allocated based on school managers’ educational intentions. Finally, using our system, lectures are allocated cooperatively through negotiation between users and coordination agent.

The contribution of this paper is in the integration of the theory, implementation and user perspectives.

References


