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Multi-agent Negotiation System for Class Scheduling

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Abstract

The current class scheduling has difficulties in reflecting students' preferences for the classes that they want to take and forecasting the demands of classes. Also, it is usually a repetitive and tedious work to allocate classes to limited time and resources. Although many research studies in task allocation and meeting scheduling intend to solve similar problems, they have limitations to be directly applied to the class-scheduling problem.

In this paper, a class scheduling system using multi agents-based negotiation is suggested. This system consists of student agents, professor agents and negotiation agents. Each agent acts in accordance with its respective human user's preference and performs the repetitive and tedious process instead of the user. The suggested system utilizes *negotiation cost* concept to derive coalition in the agent's negotiation. The negotiation cost is derived from users' bidding prices on classes, where each bidding price represents a user's preference on a selected class.

The experiments were performed to verify the negotiation model in the scheduling system. The result of the experiment showed that it could produce a feasible scheduling solution minimizing the negotiation cost and reflecting the users' preferences. The performance of the experiments was evaluated by a class success ratio.

1.Introduction

The class scheduling has been an important and complicated problem to the school administration. It has many difficulties in coordinating time conflicts and resource allocation. The class scheduling problem can be summarized as the following; first, students' preference is not sufficiently reflected in current class scheduling process. Current class scheduling is a coordination process between professor and administration. The students cannot give their preferences to each class. Besides, the students may face duplication in the classes that they want to take and have to choose only part of them in occasion. Second, the forecasting process usually depends merely on the administration's expertise. Third, the class scheduling is a repetitive and tedious process. The scheduling takes time and efforts because the administration performs the scheduling manually and iteratively to meet professors' utilities and to solve conflicts in the schedule.

If the class scheduling could be defined as the routine characteristic as the meeting scheduling result is derived, the Intelligent Agent (IA) or agent

technology can be applied instead of the users. IA can negotiate over scheduling on behalf of their associated users. IA can reflect on the users' interests and priorities, and the set of the IA, called Multi Agents System (MAS), consists of these agents that have the information about the users. The negotiation, a kind of agents' cooperation in MAS, can be a methodology to solve the conflict in class scheduling problems, and can derive the solution to the class scheduling problems with respect to the user's utility maximization. A class scheduling system is suggested by using multi agent-based negotiation. Based on the literature review of the MAS, agent-negotiation and task/resource allocation, the requirements of the multi agent-based negotiation systems are investigated by comparing to the current class scheduling systems. After the requirement analysis, the system architecture is designed and implemented. For the negotiation, the definition of the agents participating the negotiation and the interaction between the agents is presented.

2. Literature Review

The reviews for the scheduling and the negotiation between the agents in the multiagents society give many clues and ideas to model the multiagents-based negotiation system for the class scheduling process.

1. Scheduling Process

The scheduling process could be divided to the resource scheduling or allocation and the time scheduling problem although two problems overlap to the extent. The resource scheduling and allocation has been a major classical problem in manufacturing research and development. In the domain of manufacturing, it is understood as the problem of suitable assignment of manufacturing resources to tasks/jobs within a specified time window and coping with a set of constraints. [R.J. Rabelo, 1998] As mentioned above, the time scheduling problem is mainly the scheduling for the meeting of the people in groups. Anybody who has ever tried to schedule the meeting among more then three people can appreciate that some sort of automatic help would be useful. Especially the group calendars and meeting schedulers that have the information about the meeting have been one of the first groupware applications developed [Jonathan Grudin, 1992]. The most commercial systems allow the user to browse the other user's calendar in order to find an empty time slot, and schedule the meeting in that time slot.

2. University Course Timetabling

The university course-timetabling problem consists in scheduling a set of lectures for each course within a given number of rooms and time periods. If two courses have common students then they conflict, and they cannot be scheduled at the same period. Moreover, schoolteachers always teach to more than one class, whereas in universities, a professor may teach only one course. In addition, in the university problem, availability of rooms (and their size) plays an important role. [A. Schaerf, 1995]. The followings are the problems in the optimization research area; basic search problem, optimization problem, variants of the problem. Also there are the solutions for these problems in operation research area.; Reduction to graph coloring, Integer linear programming, Network flow techniques, Tabu search, Expert systems approach, Constraint logic programming approach, Genetic algorithms, Logic programming.

3. Distributed Artificial Intelligence (DAI)

Distributed Artificial Intelligence (DAI) attempts to compensate for the deficiencies of classical AI with regard to the development of intelligent agents. It is concerned with the design of distributed, interacting systems and associated questions. Consequently, it concentrates in the development of organization structures, problem solution strategies, and cooperation and coordination mechanisms for a range of distributed, knowledge-based problem-solving modules. In analogy to the human problem-solving process, DAI makes use of teams of experts who can use constructive cooperation to solve problems that for reasons of their complexity would exceed the capabilities of every individual team member. [W. Brenner, 1998]

4. Multi-Agent negotiation system

The multi-agent systems handle the meaning of negotiations in various ways. Whereas one way describes the assignment of sub-problems and resources as negotiation, another way relates to the direct one-to-one negotiation between two agents The overall aim of all negotiation activities is to permit a constructive cooperation from within the group of independently operating agents that have their won goals. Whereas the negotiation protocol provides the basic rules for the possible forms of the negotiations, the form of the negotiation process and the communication basis, the negotiation strategy depends on the specific implementation of each agent. Although the developer of an agent can provide different degrees of complexity of the negotiation capabilities, care should be taken to ensure the protocol and strategy match, that is, the selected strategy can be performed with available protocol. [W. Brenner, 1998] Depending on the situation, there may be other interaction schemes for the agents involves in the negotiation. From the individual agent's viewpoint, the objective of the negotiation can be an improvement of its own state, the support for other agents without degrading its own situation or requesting a result. Although the agent must make compromises, the capability of the overall system must be maintained. Zlotkin with this knowledge identified four forms of interaction in negotiations [G. Zlotkin, 1996]: Symmetric cooperation, Symmetric compromise, Non-symmetric cooperation/compromise, Conflict

Negotiation is proposed in DAI as a means for agents to communicate and compromise to reach mutually beneficial agreements. Negotiation is especially beneficial in multi-agent systems, where the agents are self-motivated, and where there is no central controller [J.S. Rosenschein, 1994] In [Sarit Kraus, 1995], a strategic model of negotiation [M.J. Osborne, 1990] was developed that takes the passage of time during the negotiation itself into consideration. It provides simple, efficient, and stable strategies for automated negotiators in a broad range of situations.

5. Summary and Considerations

Many approaches are suggested to solve these scheduling problems but the Distributed Artificial Intelligence (DAI) is the most meaningful method among them. The most researches select the negotiation that the agents cooperate to derive the agreement and resolve the conflict. The agent negotiation is the process of improving agreement on common viewpoints or plans through the structured exchange of relevant information.

Although many researches are introduced and prototype systems are suggested, the agent

negotiation system for class scheduling is not suggested yet. For this system, the negotiation procedure and model is designed hierarchically and the negotiation algorithm can be considered from the meeting scheduling.

3. Multi-agent Negotiation System for Class Scheduling

1.The suggested Class Scheduling Process

On the ground of the problem analysis, the requirement of new process can be derived. The suggested class scheduling process must reflect the student-sided values. That is, the time duplication of the classes that they want to take should be minimized. And the suggested process should include the forecasting of the students' demands on each class, which is helpful to the professor that assigns the class.

To satisfy these requirements, the suggested class scheduling system has the negotiation module or system. This negotiation module is the most remarkable thing in the suggested class scheduling system. It has the various agents as the users' representatives. In the negotiation system the agents can act to maximize the each user's utility. The process starts at administrator's initiating the Agent systems. The agent system comes to be the host for the entire class scheduling process. It requests not only the system to inform of the class list that has the classes' name created in the specific semester and the professor assigned to the classes but also the professors to give the preferred time information. After collecting the class information, it delivers the class list to students. According to the class list that has no fixed class time, the student can select the classes that they are eager to take without considering the time conflicts (class times duplications). In addition to the selection, they should give the bid prices that represent their preference of each selected classes quantitatively. For example, if a student selects the class A, B, C and prefers A to the others B, C, he can give the bid price to each class like (A, 80), (B, 10), (C, 10). That is, the bid price may mean the utility increment that the student will get by being able to take the class. The agent system also gets the resource information from the resource manager. The resources are the same to what is said earlier. When it collects all the necessary information, the agent system sets the various agents. In the agent system, each agent begins to negotiate the coalition to minimize the conflict and maximize the users' utilities. The algorithm used in negotiation is explained later. After the negotiation between the many agents in the agent system, the best coalition and results is produced. The agents system announces the negotiation results to students.

Above all, the suggested class scheduling system guarantees the students' utilities maximization. It reflects the students' needs and viewpoints on the class scheduling process. Because they need not consider the class time, the students can select classes that they want to take. The professor and the administrator can also forecast the students' demands of the class.

2.Agent Negotiation Model for the class scheduling

A. Formal Definition

(1) Class Scheduling

Before the investigation of the agent negotiation model, to define the concepts is necessary. The first problem for the formal definition is the class scheduling. The class scheduling is described as the problem that certain

students take the certain classes assigned by a professor. The class scheduling can be defined as following:

$$LS = (S, P, L)$$

S is a set of students (***S* = {1,2,3,…,k}**),

P is a set of professor (***P* = {1,2,3,…,m}**) and

L is a set of class (***L* = {1,2,3,…,n})**

But the set of class, ***L*** can be defined in more detail because the class is the necessary to arrange the time slots. Each class has the students, the professor and time slots allocated by the negotiation. The set of class, ***L*** has the elements, l_i that mean the specific class i. The class can be defined as following:

$$l_i = (S_i, p_i, T_i)$$

Si is a set of students registering the class,

pi is a professor assigning the class and

Ti is a set of time slot for a class.

The time slots ***Ti*** are the targets that the agents should negotiate. The time slot ***ti*** is the time of one and half hour, for example, (9:00.AM - 10:30.AM), (1:00.PM - 2:30.PM) and so on. ***Ti*** is a subset of the entire time slot set ***T***. In the negotiation system, assume that ***T*** is '5 x 5' matrix. ***T*** has 25 time slots and each time slot is labeled from 1 to 25. The 1 credit class needs on time slot. The other class with 3 credit must have the 2 time slots.

(2) Student

The student is necessary to define. As mentioned before, the set of the students is denoted by ***S***. The student selects the classes that he wants to take and gives the bid price that reflect the preference for each class. Consider a specific student ***si*** and it is defined as the followings.

$$s_i = (L_i, BP_i, O_i)$$

Li is a set of the class selected by the student ***si***,

BPi is a set of the bid price for each class, and

Oi is a set of the class type for each class - Compulsory(1) and Others(0)

(3) Professor

The professor denoted by ***P*** can select 5 favorable time slots for suggesting the alternative time slot. The professor ***pi*** is able to represent his preference to the time slot as the followings.

$$p_i = \{(preference, time\_slot)\} = \{(5, t_1), \Lambda, (1, t_2)\}$$

The professor's preference set for the time slot gives the initial time slot that the negotiation starts at. If there are more than 2 alternatives during the negotiation, the professor's preference is reflected on first.

(4) Negotiation Process and Negotiation Cost

The negotiation process is the process created by the negotiation agent to allocate the class ***li*** to the jth time slot to the class when the allocation is conflicted. The negotiation agent makes the student agents and the professor agents to participate in the negotiation process. When the conflict happens, the negotiation agent requests the student agents to suggest the bid price of the class ***li***. Then the negotiation agent calculates the negotiation cost by collecting the bid price delivered by the student agents. That is, to minimize the negotiation cost is the criterion for the time allocation of ***li***. The negotiation cost, the cost for the negotiation to allocate the class ***li*** to the time slot ***j*** is denoted by ***NCij***

$$NC_{ij} = \sum_h (bp_{hi} \times \rho_{hj})$$

bp_{hi} is the bid price scored by the student agent ***h*** for ***li***

ρ_{hi} is 1 if the student agent ***h*** has the conflict at the time slot ***j***, or 0 otherwise

The negotiation process is the iterative process between the agents to find the time slot to minimize the ***NCij***

B. Assumption for the agent negotiation system.

- Final year students should be able to register for the compulsory classes.
- The compulsory classes are less than the total number of time slots.
- The class size is regarded as the criterion for allocation because the more student the class has, the less the conflict happens.
- The time slots are considered in order.
- The professor is indifferent to the time slots that they do not assign his preference.

The final year students need the assumption 1. The negotiation agreements may not guarantee that the students always can take the registered classes. So, the students can take the compulsory classes to graduate from the school. The assumption 2 is requisite to this objective. To start the negotiation the assumption 3 functions as a kind of the policy. Although there are many criteria, the class size may be the reasonable criterion among them. It is the reason that the classes that many students take cause the less conflict. The assumption 4 is about the time slots priority for the allocation. If the time slot 16 is considered, the time slot 17 is the next time slot that will be considered. On the basis of the assumption 4, the assumption 5 is derived. The professor may be willing to receive any time slot that he likes if 5 preferred times are not feasible. These assumptions are the conditions to be able to derive the optimal negotiation agreement through the finite iterative negotiation process between the agents.

C. Rule Definition for the Negotiation

(1) Rule of the Allocation (RA).

- The compulsory classes are allocated first.
- The bigger class size is, the earlier the allocation is.
- Pre-allocated classes are not affected by the post-allocation.
- If the classes have the same class size, the class with lower code will be selected first.

(2) Rule of the Agent Negotiation (RN)

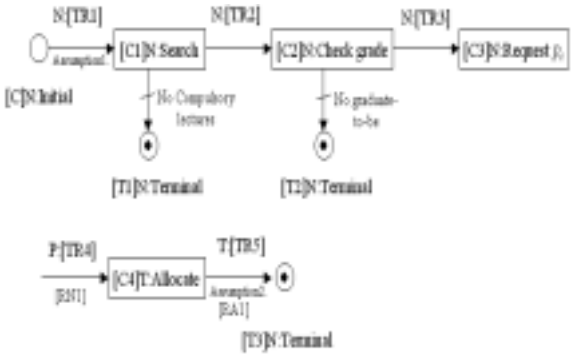
- If there are some time slots that Negotiation Cost is 0, the professor's preference is considered.
- The Negotiation is expired when the conflicts in student agent do not happen.

3. Negotiation Step Description

The negotiation step consists of 3 phases to actualize the negotiation model with the assumptions and the rules mentioned above.

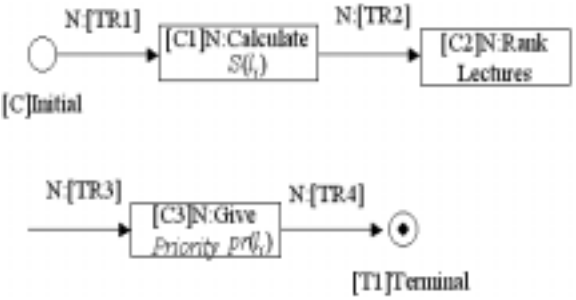
(1) Phase1: Compulsory class allocation

The assumption 1 needs the Phase1. As mentioned above, some student may not take the class required to the graduation in the negotiation agreement.



(2) Phase2: Class selection for the optional classes

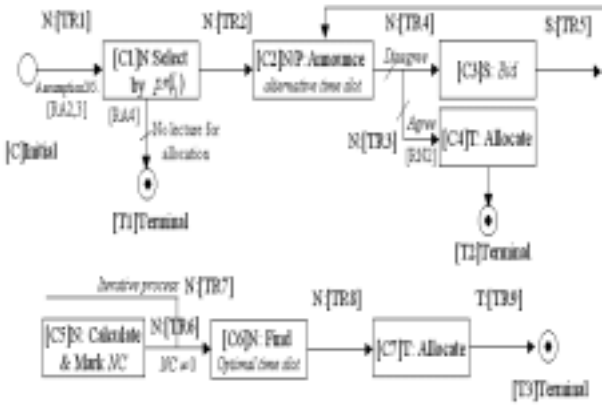
After the compulsory classes have been allocated at the phase1, the negotiation procedure confronts with the problem, which class will be the first allocation target. The negotiation agent calculates the class size of each class. The class size is the total number of students in the class *li* and denoted by ***S(li)***. It ranks the classes by the class size and gives the priorities, denoted by ***pr(li)***, to the classes for allocating them.



(3) Phase3: Optional class allocation by negotiation

The negotiation agent selects the target class by the calculated class priority ***pr(li)***. The *alternative time slot* means the time slot that is feasible in ***pi***. If it receives the *alternative time slot*, the negotiation agent announces it. If the entire student agents agree on it, the class will be allocated at that time slot and the situation becomes terminal. But if the student agents disagree on it and give the bid price because of the class conflict at that time slot, the negotiation agent must calculate and mark the negotiation cost, ***NCij***. And then it goes back to *alternative time slot.* This iterative negotiation process ends up with until the time slot with ***NC=0*** is found or minimize ***NC***

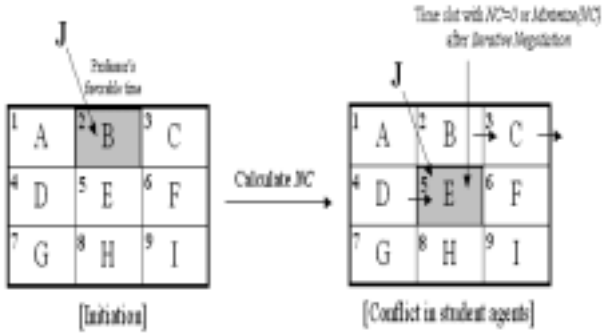
In this system, the agents communicate and negotiate with others to find the time slots with ***NC=0*** or to minimize the ***NC***. The students' interest is reflected on the class scheduling system. The next example can describe this mechanism.



4. Example of the Negotiation for the time allocation

Assume that there is '3 x 3' time slot matrix that 9 classes (A, B, …, I) that must have just 1 time slot are already allocated. And its cell, that is, each time slot has its own label that is the order for considering in the allocation problem. The professor's preferred time slot is just one and it is the 2nd time slot.

Now let new class J be allocated. The student agent meets the problem for allocating J because all the time slots have the classes. The negotiation agent starts the negotiation at the 2nd time slot. But the negotiation cost is not zero at that time slot. The iterative negotiation process is carried out and finds the time slot that the negotiation cost is zero. (The allocation in [Fig. 3.8.] ends up with the 5th time slot that the negotiation cost is zero.) If the negotiation agent cannot find the time slot that the negotiation cost is zero until it investigates all the time slot in order, it allocates the class to the time slot that minimize the negotiation cost.



5. The Negotiation Performance Evaluation

There may be many performance measures of the suggested multiagents-based negotiation system for the class scheduling systems. But the most important thing in considering the performance measure is whether the students can take their favorite class, that is, the class with the high bid price or not. From this point of view, let consider the student class success ratio, η.

$$\eta = \frac{\sum_{i=1}^{k} \eta_i}{k} \quad \text{and} \quad \eta = \frac{\sum_{j=1}^{n} bp_j \times \rho_j}{\sum_{j=1}^{n} bp_j}$$

bp_j is the assigned bid price for the class j,

ρ_j is 1 (class j registered), 0 otherwise.

This can be applied to calculate the students' utilities in the current class scheduling system and show the effectiveness of the suggested class scheduling system.

4. Conclusion & Further Research

1.Conclusion

The multiagents-based negotiation model to support the decision making related to the class scheduling was suggested. Main focus of this model is to create the students' value by reflecting the students' preferences in the class scheduling system and giving the flexibility to somewhat fixed class scheduling process. The suggested model can be characterized as follows: Negotiation based approach, Multiagents based approach, Student-side value creation, Forecasting of class demands

2.Further Research

Although the suggested system is applied to the allocation of class times, the resource allocation of each class is also important, because the resource constraints will restrict the negotiation agreements. Also, users should be able to represent his preference to the classes in addition to the bid prices. More research on the other criteria to select classes or give priority is also needed.

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