Paper:

Applying Multi-Agent Algorithm to a Class Scheduling System

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We propose a multi-agent algorithm to solve a scheduling problem. The proposed application takes into account various restrictions relative to Japanese university class scheduling in particular. A multi-agent system consisting of agents representing the requirements and restrictions for professors and departments are introduced. Scheduling is solved using negotiation between agents together with the hill-climbing method. Through a software simulation, we were able to show that our proposed method successfully applies the self-organizing nature of agents to solve the scheduling problem.

Keywords: multi-agent, scheduling problem, agent negotiation, hill climbing method, self-organization

1. Introduction

Emergence and self-organized behavior in agent systems has become an important tool or feature in solving complex real-world problems, where straight-forward system design fails to yield satisfactory or sufficient results.

For this research, we aim at applying a self-organizing agent system to a particular real-world problem, namely the class (course) scheduling problem for the author's university. Our direct goal is to create a satisfactory solution for a complex real-world scheduling problem, but our underlining motive is to study the self-organized behavior in such a working agent system. Our hope is to determine key aspects of self-organizational behavior and understand the basic mechanism of the resultant complex behavior.

Class scheduling is a scheduling problem where limited resources (i.e. professors, classrooms, time periods) must be assigned appropriately. Especially for the case of university class scheduling, there exist specific restrictions and constraints, for example constraints on the days or hours a specified professor can teach, requirements on hardware used for class, or ordering of courses. The various constraints make university class scheduling a complex and time consuming problem to solve.

For this research we solve the university class scheduling by using negotiation between agents. One type of agent, a department curriculum agent, tries to solve the scheduling problem regarding placement of professors and appropriate classrooms for each class year of each department. Another type of agent, a professor agent, tries to solve the scheduling problem regarding constraints for each professor. The class schedule is evaluated using a violation point method, and the strategy used for the agent negotiation is based on a hill-climbing method targeted lower the violation points.

In the proposed system, the class scheduling problem is solved using the following 3 steps;

1) Initial allocation of classes and professors taking into account course constraints.

2) Department curriculum agent negotiation to solve constraints for professors and classrooms.

3) Professor agent negotiation to solve constraints for professors.

This paper is organized in the following order;
First we give a description of self-organized agent behavior. Next the problem domain of the class scheduling problem is described. Following, the agent system specification and schedule negotiation is given. Finally we close with discussion of results and future topics.

2. Self Organization

It has been reported by various researchers [1] that design of effective organization of agents is crucial for the construction of an efficient multiagent system. The Distributed Artificial Intelligence (DAI) community and other disciplines have begun to apply evolutionary processes in order to achieve self-organization of multiagent systems [2].

Self-organization seen in nature is the phenomena in which complex structures or systems are created from apparently self-induced organization of simple components. The complex crystalline structure of snow flakes is an example. For this paper, self-organization in multiagent systems is defined as the emergence of macroscopic organized behavior of a multiagent system from an initial unorganized state, achieved through the microscopic interaction of the constituent agents. In a self-organized multiagent system, the final state of the total system achieved is

Table 1. Course data example.

Department	Year	Course No.	Course Name	Requirement type	Constraint	Period	Pre-requirement	Hardware Requirements
Inf. Systems	2	1201a	Software Basics	Required	Pair with 1201b	2		
Inf. Systems	2	1201b	Software Basics Lab	Required	Pair with 1201a	2		PC
Inf. Systems	2	1202	System Design	Required		1		
Inf. Systems	2	1203	Artificial Intelligence	Elective		1		
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Inf. Systems	3	1301a	System Programming	Required group Elective	Pair with 1301b	1	1201a	
Inf. Systems	3	1301b	System Programming Lab	Required group Elective	Pair with 1301a	2	1201b	PC
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

more organized or complex than the initial state, but this self-organization is achieved by a bottom-up approach, in which each agent only has local goals and a limited view of the total system. Through the local interaction or microscopic behavior of the agents, the global interaction or macroscopic behavior of the total system is constructed.

Recently there has been some research in modeling self-organization in multiagents. Far et al. [3] proposes that in a purposeful (i.e. not random) organization, Organizational Intelligence (OI), is a property of interaction among agents, and can only be ascribed to at least a pair of agents. Goldman et al. [2] has used the Game of Life to analyze the patterns of self-organizing agents. Parunak et al. [4] proposes an entropy model for self-organization in multiagent systems. Using the entropy model, it is possible to achieve self-organization in the macro level of the system while the system shows an increase in entropy (loss of organization) at the micro level among agents. Parunak notes that in order to model self-organization, it is important to view the system explicitly in terms of macro and micro levels. Horling et al. [1] proposes a model for analyzing and diagnosing the effectiveness of organizational structures for multiagent systems.

For the presented research, we follow from other papers in applying the self-organizing behavior of multi-agent systems. But for this paper we apply a multi-agent algorithm to a real-world complex problem rather than toy problems as in other papers, and verify the validity of self-organizing multi-agent systems to such problems.

3. University Class Scheduling Problem

Class scheduling is a real-world complex scheduling problem. For this research we take the case of an actual Japanese university system, but efficient algorithms solving the class scheduling problem can be applied to a wide range of similar scheduling problems.

Class scheduling implies the necessary scheduling of classes (courses), classrooms, and professors, all within limited class times. In this case, we take the case of class scheduling for the author's university, Tokyo University of Information Sciences.

Table 1 shows examples of the course data used for scheduling. Laboratory courses require specific ordering of classes and specified hardware in classrooms, and create complex constraints in the scheduling.

Assumptions for the class and professor assignment include;

1. The range of classes (courses) each professor teaches has been predefined.
2. Which semester the classes (courses) will be held has been predefined.
3. Every class is assumed to be held (i.e. minimum students will take the class)
4. There are enough classrooms and time allotments in the whole week to allow all necessary classes to be held in the semester, but not in over abundance so that most classrooms will be used throughout the day for the whole week.
5. There is a wide range of classrooms available, from different seating capacities and hardware facilities (i.e. projectors).
6. There are 5 class days a week. 5 class periods (90 minutes each period) in a day.

Table 2 shows the constraints for the scheduling problem.

4. Multi-Agent System

For this research, a multiagent system is applied to solve the scheduling problem. Here we define a multiagent system as a system in which autonomous software entities, called agents, cooperate to perform some global