Managing Operations in Multiagent Virtual Organizations (Extended Abstract)

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ABSTRACT
In this paper we present our method and experimental results for handling virtual organization (VO) task management operations. First, we present a combinatorial auction approach to the initial commitment decision problem, which determines how a team task (i.e. VO task) can be allocated to a team of agents forming a virtual organization, while taking into consideration that the agents may be of different nature and they have other (their own) tasks in addition to the VO tasks. Then we present our solution to the crisis management problem, which determines at run time what to do when an agent decides to abandon a previously committed task in order to pursue a newly arrived, better task. We have built a testbed for evaluation of the strategies and used a building construction domain problem to show the effectiveness of our approach.

Categories and Subject Descriptors
I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence – *Intelligent agents, Multiagent systems, Coherence and coordination.*

General Terms
Algorithms, Design, Economics, Experimentation

Keywords
Description: experimental/empirical (architectures / systems / simulations / data analysis). Inspiration: artificial intelligence, distributed systems, economics. Focus: Social/Organizational Structure.

1. INTRODUCTION
A virtual organization [1,7] can be defined as "a cooperation of legally independent enterprises, institutions or individuals, which provide a service on the basis of a common understanding of business. The cooperating units mainly contribute their core competences and they act to externals as a single corporation. The corporation refuses an institutionalization – for example, by central offices; instead, the cooperation is managed by using feasible information and communication technologies" [8]. One example of a virtual organization in the building construction domain would be a group of independent agents participate in construction projects. There, external buyers offer the projects, developers plan, manage, and coordinate the construction related activities, and building contractors bid on the projects and perform the construction tasks. To generalize, we identify three general types of agents in a virtual organization: (1) the buyers, who purchase product or service from the virtual organization, (2) developers, who manage and coordinate the activities in the virtual organization, and also responsible to form the virtual organization, and (3) the contractors, who are the ones who actually perform the tasks.

Once a virtual organization is formed, the contractors show their affinity for selection of a plan that leads to the completion of the product/service. A plan would include a set of tasks and temporal constraints, so the contractors may decide to be involved in the plan by pledging one or more tasks that the agent believes it could finish. While the agents submit their pledges (in exchange for rewards for accomplishing the tasks), the developer would decide which plan should be selected and which agents' pledges are assigned. This is known as initial commitment decision problem (ICDP) [2]. Once a plan is selected, agents are committed to perform tasks as assigned by the developer. However, these agents also receive tasks in real-time that do not belong to the virtual organization. Since it is committed to some tasks in virtual organization, it may lose opportunities of having more profits. On the other hand, abandon the commitment to VO plan subtasks may put the overall plan in jeopardy. To improve the performance of the virtual organization and the individual agents, *Crisis Management* mechanism is needed.

2. INITIAL COMMITMENT DECISION
To solve ICDP, we propose a combinatorial auction [5,6] approach. Each agent generates a bid to select a plan based on its local reasoning process. The bid will include a heuristic called the *preference number*, which shows the agent's likeliness of implementing that plan, together with the VO subtasks it can perform without affecting any previously committed tasks in the agent's local schedule. The developer analyzes the structure of a newly arrived VO task (from buyer) and generates several tentative plans in its plan library and wait for agents to bid for each plan. The developer then finds the highly preferred plan

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using a winner determination mechanism, thus obtain a solution to the ICDP as the result of the combinatorial auction. The scheduling and the management of the tasks are done using the *Simple Temporal Network (STN)* [3,4]. We also include, in our agent model, two attributes: *Role* and *Nature*:

- The *role* of an agent bounds it to perform the tasks of its expertise only. For example, a plumber agent can perform tasks related to plumbing only. However, an agent may be versatile and can have multiple roles.
- The *nature* is similar to the nature of the investors in the business world - aggressive or conservative. An aggressive agent tends to be more responsive (i.e. efficient) to changes in the system (such as new tasks), whereas a conservative agent may be more likely to skip bidding a subtask even if it has time available. We assign each agent a numeric value to indicate their different level of aggressiveness.

Our experiments show that by utilizing the preference feature that takes into consideration of the nature of agents, all agents have increased profits.

3. CRISIS MANAGEMENT

The key idea in our crisis management method is to encourage other agents to perform the abandoned subtask by offering incentives and, at the same time, penalize the agent who did not complete the task which it had committed. Two penalty policies are implemented and tested:

- A *linear penalty policy* has a fixed penalty rate for each unfulfilled commitment, and
- A *progress-based penalty policy* has a decreasing penalty rate as more commitments have been fulfilled. It charges a heavy penalty if the agent cannot fulfill a minimum percentage of its promises, and it charges less penalty if the agent has fulfilled a certain percentage of obligations. For instance, if the agent cannot fulfill 30% of its promised commitments, there are 100 units penalty for each unfulfilled commitment; if the agent has fulfilled 90% of its promise, there is only 10 units penalty for each unfulfilled commitment. Progress based penalty policy is dynamic and depends upon how many VO tasks have been accomplished at given time.

Without crisis management, de-commitment of VO-tasks should be discouraged. This means that, a direct task (i.e. non VO-task) would be accepted only if there is no conflict with VO subtasks in the agent's local schedule (conflict with other direct tasks are still allowed). With crisis management, when the new direct task conflicts with a VO subtask, the agent checks if there is still a profit when accepting the direct task and paying the penalty for the pre-committed virtual organization subtask. Once the contractor agent decides to reject the pre-committed VO subtask, it will notify the developer agent and wait for its approval. The developer sends a request to complete the VO subtask left by a contractor agent to other contractor agents with the same role, so they may pick it up. The price of this VO subtask now increases - the new price of this leftover VO subtask is equal to the original price of the VO subtask plus the penalty paid by the contractor.

With higher price, other contractor agents are more likely to accept this VO subtask. Once the other contractor agents receive the request by the developer agent, it performs feasibility check. However, in this case the agent cannot replace a VO subtask that is already scheduled in its local schedule to perform another VO subtask (i.e. the leftover subtask of another contractor). This is done in order to prevent deadlock situation.

Crisis management ensures some freedom of the contractor agents to complete its pre-committed direct tasks and to accept more direct tasks during the execution of the virtual organization. Experiments show that the implementation of crisis management boosts the agents' performance while maintaining the completion of the virtual organization task as assigned by the buyer, and the progress-based penalty policy in general outperforms the simple linear penalty policy.

4. EXPERIMENTS AND CONCLUSION

We have also created a testbed for multi-agent virtual organization applications. This testbed allows us to rapidly develop and VO applications and evaluate mechanisms for virtual organization operations. We conducted our experimental work via simulation on an imaginary building construction domain problem. Our results show much better efficiency of the agents in virtual organizations when our solutions to ICDP and crisis management are employed, and at the same time offering more flexibility and better representation for agent planning.

5. REFERENCES

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