A TEAM-BASED ORGANIZATIONAL MODEL FOR ADAPTIVE MULTI-AGENT SYSTEMS

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Abstract: Proper organizational modelling is a challenging issue in complex cooperative multi-agent systems. In this paper, we propose a team-based multi-agent organizational model, based on the Schwaninger's model of intelligent human organizations. It provides an integrative framework to rapid task handling, the main effectiveness requirement in many applications. Adaptation via reorganization makes the model suitable for dynamic, uncertain environments. Fast initial team formation, greedy capability-based coalition formation, and using the nearest neighbours' resources improve utility compared to the identified hierarchical organizational models.

1 INTRODUCTION

Our everyday lives and specially our social transactions require various types of coordination that incorporate decision making process within a dynamic uncertain environment under multiple constraints. Cooperation between members is an important coordination task which aims to maximize the overall utility. Multi-agent systems (MASs) have been widely used to model and probe the complex behaviors in such cooperative systems.

Using organization theory, behavior of individual agents can be described by the roles they adopt and behavior of MAS may be predicted as the result of their overall actions.

Organizational models defined for MASs are mainly adopted from analogue models in human communities (Boella and Van Der Torre, 2006).

In real world, we may face emergency systems which need fast task handling. This rapidity is the main effectiveness requirement of the system. Rescue in emergency situations is an example, where cooperative humans tend to use all their capabilities to rapidly perform the tasks. They may even prefer to act out of their role-specific responsibilities in occasional situations.

In this paper, we propose a team-based multi-agent organizational model, based on the Schwaninger's model of intelligent human organizations (Schwaninger, 2009). It provides an integrative framework to rapid task handling.

Following, section 2 discusses some related work. Section 3 introduces the proposed organizational model. Section 4 shows some experimental results, and in section 5 we conclude.

2 THEORY AND RELATED WORK

A multi-agent organization can model a MAS as a group of distributed agents following a common goal. The interactions between the agents, the relationships between the agent roles, and their coordination style make the organizational design.

Several organizational Structures are introduced in literature (Deloach and Matson, 2004), (Horling and Lesser, 2005), (Kolp, Giorgini, Mylopolos, 2006) for modeling MASs. Besides, a variety of adaptation methods for different organizations have been proposed yet (Ghijsen, Jansweijer, and Wielinga, 2009), (Kirn and Gasser, 1998), (Kota, Gibbins, Jennings, 2009), (Martin and Barak, 2006), (Rosenfeld, Kaminka, Kraus, Shehory, 2008. All of these methods attempt to enhance the system effectiveness using adaptation.

(Ghijsen et al., 2009) and (Kota et al., 2009) are among the latest works performed in this field. In (Kota et al, 2009) a Decentralized structural adaptation method is proposed, where agents need to reevaluate all their relations in each time step. This

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reevaluation decreases efficiency regarding increasing computation. It doesn't consider environment openness.

In (Ghijsen et al., 2009), tasks are made of sub-tasks which are distributed among agents in lower levels of hierarchy to be performed by them. However, in many applications tasks should be performed by groups of agents. Besides, organization efficiency should be improved.

3 ORGANIZATIONAL MODEL

Organization model of MAS defines the structure, roles and interaction pattern of constituting agents, and the goal(s) of the system (Mintzberg, 1993). Schwaninger (2009) has presented a comprehensive organization model for intelligent human organizations, as follows: An intelligent organization is capable of changing to adapt with varying environment, mutual effect on the environment, and viability in the environment of its comprehending organizations. In this model design, control and development are known as main components in systemic management that should be considered along with system identity structure. A framework including five aspects of activity, structure, behavior, ethos identity vision, and time seems appropriate to model an organization.

Here, we define structural model (that shows organization designing), activity model (that shows the entire functionality of organization) and behavior model (that shows cooperation process of organization components) to introduce an emergency-response cooperative MAS. The time dimension of schwaninger's model is inherently purposed in all structure, behavior, and activity models. The fifth dimension of the model includes ethos, identity, and vision. It is the center of paradigmatic change, which hardly affects on all three domains: Structure, behavior and activity. It will be paid more attention in our future works.

3.1 Task Model

As mentioned in (Carley and Gasser, 1999), (Horling and Lesser, 2005) and (Dignum, Dignum, and Sonenberg, 2004), a task is an activity that should be performed by one or more agents to achieve a goal or make a certain affect on the environment.

We assume each task as a discrete event that may occur with a given statistical distribution all around the environment and in every point of time. Here we suppose that the spatial and temporal distribution of tasks' occurrence is random.

A task is a tuple of two spatial attributes, which describe the center of event occurrence, and a vector of required capabilities and the minimal level of each capability to be completed. The capabilities are selected from a definite set in the system. We assume that all these features are received by task occurrence sensing agents.

Hence, if $C=\{c_1,c_2,...,c_n\}$ denotes all the n capabilities available for agents, then $T=\{(x,y),(c_1,v_1),(c_2,v_2),...,(c_n,v_n)\}$ describes the task occurring in a point with dimensions x and y, requiring capabilities $c_1,c_2,...,c_n$ with at least $v_1,v_2,...,v_n$ necessary levels of each. Here, these values come from a range between 0 and 100.

3.2 Agent Model

In this paper, we supposed that the agents are homogeneous in potential capabilities, but different in the power to use each capability. This power is related to available resources for the agent. Besides, we assumed agents in two roles: Supervision and Operation. Hence, if we have an agent set $A=\{a_1,a_2,...,a_p\}$ in the context (p is the number of agents), each agent $a_i \in A$ may contain a tuple of attributes as follows:

$$\begin{gathered}\{(x,y),(c_1,v_1),(c_2,v_2),...(c_n,v_n)\}\\ \forall x:1..n, v_x \in [0,100]\end{gathered} \tag{1}$$

3.3 Structure Model

Organizational structure defines informational, controlling, communicational patterns and features of task environment (Kota et. al, 2009), (Schwaninger, 2009). Our proposed organization is a team-based organization whose initial structure forms once the system begins to work and reorganizes during the system operation, along with occurrence of reorganization triggers. The environment is a two dimensional grid space in which a number of agents have been distributed following a statistical distribution pattern. The agents are distributed randomly or based on a given map around the environment.

Figure 1 shows the proposed structure model. In this model, the initial teams form based on the location of each agent to minimize cost of initial team formation. The context is partitioned to some segments and all agents placed in each segment form a team. The number of segments is varying as one of the system parameters.

As mentioned in (Mintzberg, 1993), a supervisor is required to manage each team. Here, the manager of each team is the eldest agent among all team members. Thus, it avoids any cost to system for this task as well as the experience factor has been implicitly regarded for selection of supervisor.

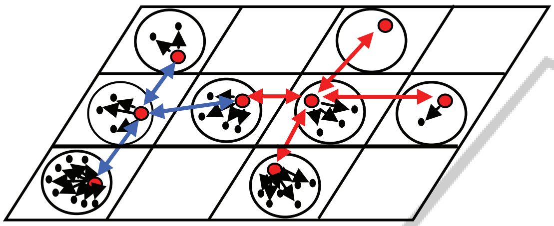

Figure 1: Organizational Structure.

3.4 Behaviour Model

Behavior model of proposed organization indicates the way system transforms from one state to another upon a given trigger. Occurrence of a new task event, entrance of a new agent to the system, and exit of the agent from the system form such triggers. We use decentralized reorganization to coordinate the MAS components.

It seems that coalition formation algorithm used to select sub-teams and if needed, selection of accommodator agents taking from adjacent teams, are very significant in organization efficiency. In this research, the simple greedy algorithm is used.

3.5 Activity Model

As Schwaninger (2009) defines, the activity model describes the overall intended operations of or actions taken by the organization. The emphasis of change is on revising principles, goals and rules that control and affect on the behavior of the organization. Our proposed reorganization method affects only on organizational structure.

We defined the utility as the rate of completed tasks divided to the mean task accomplishment time.

$$\text{Utility} = \text{TaskCompletionRate}/\text{MeanTaskCompletionTime} \quad (2)$$

4 EXPERIMENTAL RESULTS

Our experiments consist of two parts. For first part, we compare the impact of workload distribution in team-based and hierarchical organizational models using RoboCupRescue simulator.

In (Ghijsen et al., 2009), the performance of organization is measured under two conditions. In the first, civilians (tasks) are distributed randomly in the environment to show a homogeneous task distribution. In the second they are distributed as clusters to form a heterogeneous workload. We run some simulations on the Kobe map, creating 5 different homogeneous and 5 different heterogeneous task distributions, as Ghijsen et al. (2009) performed. Each distribution contains 9 agents (ambulances to rescue civilians) and 20 tasks (civilians). Each simulation finishes after 300 time steps. Figure 2 shows the results. Direct Supervision, Standardization, and Adaptive hierarchy are three coordination methods which are introduced, implemented, and compared in (Ghijsen et al., 2009).

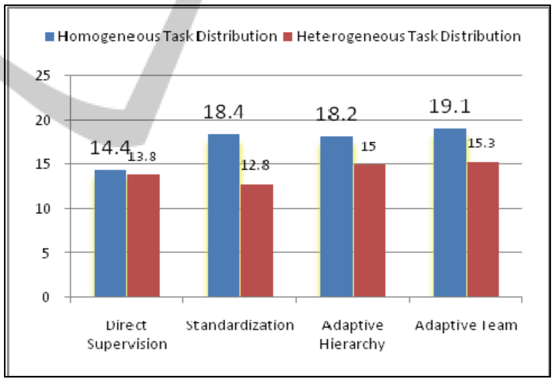

Figure 2: Average number of tasks successfully performed using four models (Performance).

As figure 2 shows, team-based method causes better performance than hierarchical ones. It is because of rapid initial team formation and proper load distribution between agents as teams. In homogeneous task distribution, this is done better because the tasks are almost uniformly distributed between agents. In heteregeneous distribution, the tasks are distributed as clusters and the agents near that clusters are mostly involved in task handling. So, the team-based model doesn't improve the performance as in homogeneous one.

For second part, we compare the hierarchical and team-based models against the rate of successful task handling. For small numbers of agents, the models are comparable and their effectiveness is in the same range. But for agents more than 50, the team-based model had much better results. The results show smooth changes in utility function when increasing the problem size. It shows that the proposed team-based model is scalable enough to be used in medium-scaled multi-agent environments.

Figure 3 shows the changes of utility function with increasing problem size. It seems that fast team formation, proper load distribution between agents, and team-based task handling cause the system to perform effectively.

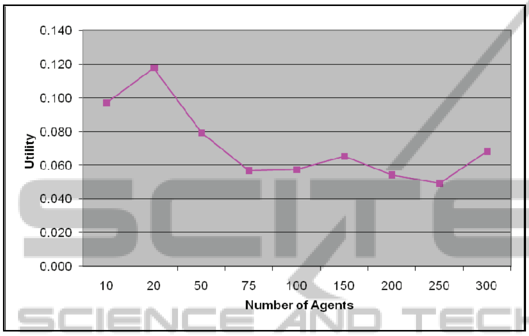

Figure 3: Utility of team-based model in different problem sizes.

5 CONCLUSIONS AND FUTURE WORK

In this paper, the problem of decentralized adaptation is addressed and a team-based organizational model is proposed based on schwaninger's model of intelligent organizations. The main reason for this selection was the importance of changeability for organizations acting in open, dynamic and uncertain environments. The agents are coordinated through reorganization via fast coalition formation, and a greedy task allocation method is used.

Experiments show the better effectiveness of team-based model against the hierarchical one. Adaptation via reorganization, fast initial team formation, greedy capability-based coalition formation, and using the nearest neighbors' resources, improve utility.

Future work will involve proposing new coalition formation algorithms and testing the effect of task and environment factors on system efficiency. We are going to develop a more effective simulation environment to be able to support the open, dynamic, and uncertain environment's properties. Varying agent capabilities, different types of tasks, variable number of segments, changeable agents' sights, and controllable output information are some features to be added to developed tool as soon.

REFERENCES

Boella, G. and Van Der Torre, L. (2006). Coordination and Organization: Definitions, Examples and Future Research Directions. *Electronic Notes in Theoretical Computer Science*, 3-20.

Carley, K. and Gasser, L.(1999). Computational organization theory. In Weiss, G.(Ed.), *Multi-Agent Systems, A Modern Approach to Distributed Artificial Intelligence* (pp. 200-330): MIT-press.

DeLoach, S., and Matson. E. (2004). An Organizational Model for Designing Adaptive Multiagent Systems. In *Proceedings of the Eighteenth National Conference on Artificial Intelligence (AAAI-04).* San Jose, CA.: AAAI Press.

Dignum, V., Dignum, F., and Sonenberg L. (2004). Towards dynamic reorganization of agent societies. In *Proceedings of Workshop on Coordination in Emergent Agent Societies* (pp. 22-27).

Ghijsen, M.; Jansweijer, W. N. H., and Wielinga. B. J. (2009). Adaptive Hierarchical Multi-Agent Organizations. In Babuska, R. and Groen, F.C.A.(Eds.) *Interactive Collaborative Information Systems*. in press.

Horling, B. and Lesser, V. (2005). A Survey of Multi-Agent Organizational Paradigms. *The Knowledge Engineering Review*, 19(4), 281-316.

Kirn, S. and Gasser, L. (1998). Organizational Approaches to Coordination in Multi-Agent Systems, Technical report, Ilmenau Technical University, Germany.

Kolp, M., Giorgini, P., and Mylopolos, J. (2006). Multi-Agent Architectures as Organizational Structures. *Autonomous Agents and Multi-Agent Systems*, 13(1), 3-25.

Kota, R., Gibbins, N., and Jennings, N. (2009). Decentralized Structured Adaptation in Agent Organizations. In: *Organized Adaptation in Multi-Agent Systems. Lecture Notes in Computer Science,* 5368, 54-71.

Martin, C. and Barber, K. S. (2006). Adaptive Decision Making Frameworks for Dynamic Multi-Agent Organizational Change. *Autonomous Agents and Multiagent Systems*, 13, 391-428.

Mintzberg, H. (1993). *Structures in Five: Designing Effective Organizations*. Engelwood Cliffs, N.J.:Prentice Hall.

Rosenfeld, A., Kaminka, G., Kraus, S., and Shehory, O. (2008). A Study of Mechanisms for Improving Robotic Group Performance. *Artificial Intelligence,* 172, 633-655.

Schwaninger, M. (2009). *Intelligent Organizations: Powerful Models for Systemic Management* (2nd ed.): Springer.