Rapid Adaptation in Computational Organizations

S. Alqithami[1], **and H. Hexmoor**[2]
Computer Science Department, Southern Illinois University, Carbondale, IL, USA

Abstract – *Primarily, we describe a computational model of organizations where agents rapidly adapt to changing environmental conditions. We consider an organizational model with properties of roles, utilities, capabilities and norms (RUCN) in order to give the agents the opportunity to quickly adapt to any new environment. Moreover, a simulation volleyball game is implemented using Netlogo and has been thoroughly described in order to illustrate the model.*

Keywords: Fast adaptation, multiagent, computational model, organizations.

1 Introduction

Multiagent systems are very useful for building a system that can codify interactions among a group of independent and disparate players (i.e., agents). There are two kinds: a closed system is one with a single structure and fixed objectives. In contrast, an open system allows agents to enter and exit dynamically [16]. Moreover, dynamic capability evaluation is used to choose, a priori, the ability of agent instances to form an organization or complete the set of organizational requirements [14]. We will consider a closed multiagent system since the number of agents inside the organization in our model is constant.

Agents usually interact with each other inside a virtual organization. A virtual organization is a set of individuals or institutions anticipated to share resources by following sharing rules [9]. Virtual team or organization is a general word used for a task, organization or project, which is characterized by multiple locations (i.e., dispersion), division of responsibilities (i.e., empowerment), restlessness (i.e., acceptance of change), interdependence and all members' cooperation is needed. The changes inside the organization are stable, for it is dynamic in nature. The organizations may have a sufficient structure since it has been companied with a multiagency platform. Therefore, if it is able to transmit the capability from its current state to the next, it will consider a self-adapting organization [15].

In order to illustrate how the agents communicate with each other, we need to define self-adaptation in multiagent systems. Self-adaptation systems are able to change the agents' organization without a centralized, explicit, implicit, external or internal control. Such a system can be reorganized as a result of planning carried out by internal central control [17].

We will outline this paper by highlighting some previous work and related background research in section two. In the third section, we will illustrate the four main concepts of building rapid adaptive organization (roles, utilities, capabilities, and norms), and implement them in order to provide a simulation for a volleyball game. Finally, we present concluding statements in section four.

2 Background and Related Work

The organizational model used in this paper was first introduced in [11]. The author showed that the organization has a utility that is composed from productivity, synergy and fitness, represented in equation 1.

$$U\,(A, R) = P\,(A, R_i) + \left[\left(\frac{1}{sizeof(R_i)}\right)\sum S(i,j)\right] \quad (1)$$

A is an agent and R_i is the i^{th} role. The organization in general depends on the team capabilities (C), roles (R), departments (D), and norms (N). We also applied power to the edge (PE) algorithm to the organization because it is more empowered, superior, interoperable, agile, and has better shared awareness. The organization has been described as a set of capabilities that show the agents' capabilities in a specific range, roles for agents, departments that prescribe what a set of agents will do within specified roles, and norms of interaction among individuals. Moreover, the utility for the agent can be determined by productivity, synergy, and level of fitness. Some of the requirements that should exist for better achievement inside the organization are presenting a set of rules, organizational type, active environment, switching rules, monitoring agent performance, and verification of fitness.

Matson and DeLoach's approach to reorganization of Multiagent systems (MAS) originally involves the evaluation of the system's ability to perform a desired task [14]. Based on this evaluation, agents may decide to either proceed to satisfy the organizational goals, relax some goals, or abandon the process of reorganization and task acceptance altogether. The foundation of this approach is an organizational model consisting of goals, roles, agents, and capabilities. Based on this model, certain evaluative constraints are applied to the process. First, there is knowledge of which agents are available for inclusion in the system. Second, it must be determined what necessary capabilities exist in order to satisfy the demands of a role. Third, an assessment of the capabilities of all available agents must be made to determine their respective qualifications for acceptance of a given role. To perform this step, the authors have devised a capability taxonomy rooted at the abstract level. Leaf nodes of this taxonomy represent concrete functions and capabilities of an agent, such as the types of sensors (sonar, infrared, light, etc.) and motivators (wheels, tracks, etc.) the agent is equipped with. Finally, limitations applied to roles must be taken into consideration.

Zhang and Zhang relegate the decision to the developer in order to choose the best subtasks [19]. Afterwards organization enters the formation process. In the negotiation process, the agents send their offers (i.e., bids) for finishing the job to the developer and each related subtask will appear in a separate bid. Then, the developer will start to select the optimal membership for the agent with the best offer from the first bid using a recursive best first research (RBFS) and heuristics algorithm. The agents may receive penalties for lack of commitment depending on the tasks that have not been satisfied as determined by the developer. Moreover, the agents are capable of making rational decisions during their operation because they incorporated the motivation quantities framework (MQ) for the task selection process. They model the agent performance, promise and penalty using the utility mapping function. Furthermore, they have mentioned a statistical model to predict and analyze the agent's behavior and the impact on the organization utility.

Furthermore, Zhang and Zhang represent five of the relationships among the three components of any organization builds [19]. The organization in general consists of individuals, tasks assigned to those individuals, and resources to accomplish certain tasks. The first type of relation is the precedence; it sorts the tasks inside the organization depending on specific mechanisms that map the temporal dependencies, like using the PERT chart to build a set of ordered pairs of tasks. Second, they represent commitment of recourses because most of the resources are required for specific tasks. The third is to assign personnel to accomplish certain tasks. Then, since most of the personnel inside the organization have different access to each other, networks among the different personnel are applied as the fourth relation. The fifth is skills that include all resources accessed by the individuals inside the organization. Moreover, the authors show that PECANS model might be applied in Thompson's theory of interdependence to show some extension to it [12].

THOMAS architecture focuses on the design of virtual organization to allow the multiagent systems in dynamic environments to deal with decomposition and abstraction. It offers a total integration to enable agents to transparently offer and request services from other agents or entities, and allowing external entities to interact with agents by using the services provided. There are three components in THOMAS: service facilitator (SF), platform kernel (PK) and organization manager service (OMS) that have the three main structural components: rule, norms, and unit [3].

Dignum provides a general overview of dynamic reorganization concepts and examines two metrics useful in examining MAS performance [6]; society utility and agent utility. Society utility is further decomposed into the success of interactions, roles, and structures in the system. Agent utility is not clearly defined, as it differs from agent to agent in heterogeneous agent systems. In addition to these utility metrics, several types of reorganization "maneuvers" are classified [7]. The first of these, pre-emptive reorganization, is a viable option in unpredictable environments where possible, or likely, events can be prepared for in order to take full advantage of them. Protective reorganization attempts not to take advantage of possible future events, but instead works to limit the negative effects of such events on the system. Exploitive reorganization takes place after the fact, and seeks to benefit from events that have already taken place. Finally, corrective reorganization attempts to lessen the damage caused by events which have previously occurred in order to maintain system usefulness. Specific methods for performing adaptation are not present in [7] but it provides many useful ideas for developing new methods or for elaborating on existing methods [2].

3 Fast adaptation

The organizational adaptation research is challenging since it accounts for multiple player interactions inside the organization. Joshua Epstein has reported a model that permits autonomous agents to be endogenously created in internal organizational structure in order to adapt optimally to a dynamic environment [8]. Wu, et. al. [18] report on a relevant research by building an organizational adaptation with suitable centralization instead of a hierarchy algorithm using four proportions: agility, robustness, resilience, and survivability.

Before we proceed, we should have a better understanding of the four central concepts of utility, norms, role, and capability that we are going to use in order to build this model. Utility is different among agents inside the organization and the outcome space is very large, which makes it difficult to predict actual levels. Our approach is to observe agents' behavior over time and to build a scale for it [4]. The second concept is norms, which are similar to rules that restrict and describe behaviors most of the time for multiagent systems [10]. In different ways of formulating norms, they can be used to guide selection of different roles because they are able to interact with normative multiagent systems [1]. Roles are used for the organizational function in order to specify the assignments for the agents inside. Finally, capabilities usually cause reorganization inside the team itself because they are dynamically changing over time, and here, they have been defined as the ability to show information in specific areas [14].

After we have applied the main concepts for building a multiagent model, we will discuss implementation issues outlined in our model. Our implemented system uses the

Netlogo platform, which is a java based cross-platform testbed for simulating natural and social phenomenon in order to build a multi-agent program modeling environment. A volleyball game will be used as an example to illustrate the issue in an obvious manner, as in Figure 1.

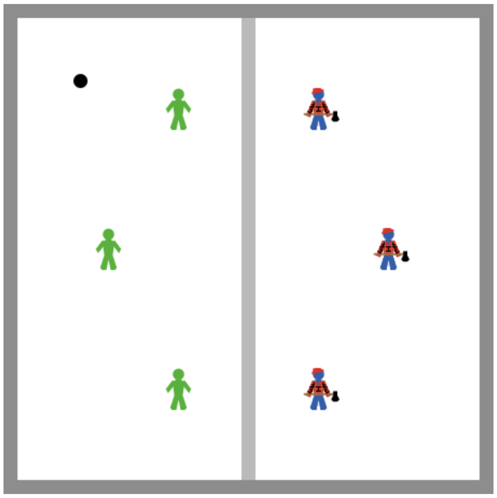

Figure 1. A screen snapshot of Volleyball demonstration in Netlogo

We implemented two teams as illustrated in Figure 1. The one in the right which represents agents in the shape of lumberjacks is the USA team, and the other in the opposite side which represents agents in the shape of people is the KSA team. The idea of using these shapes is to differentiate between teams. Also, we have implemented a small number of players because it is the least number of personnel needed to illustrate an organization and to keep the game simple. The positions for the agents inside the simulation were distributed as randomly as possible (i.e., serendipitously) as in the real world. The players interact with each other and with the ball according to the game's theoretic payoff matrix shown in Table 1.

Table 1. The game's theoretic payoff matrix between the two teams

		USA		
		P1	**P2**	**P3**
KSA	**P1**	0 , 0	1 , 1	2 , 2
	P2	1 , 1	0 , 0	1 , 1
	P3	2 , 2	1 , 1	0 , 0

As shown in Table 1, the set of $< P_1, P_2, P_3 >$ represents different players in each team, and their payoffs will be differentiated depending on the players with whom they are interacting. Thus, the player will get a higher payoff toward the opposing team if his main concepts are higher than the opponent player, detailed in table 1. However, it might be easy to find a strict pure-strategy Nash equilibrium precisely in this manner because one agent has the best response to the strategies of the others inside its team [13]. Besides, the only way to have a chance of scoring in the current moment, whether the opponent gets a fair payoff or not, is to let the player get the ball into the opponent's field with a better payoff when the distances among them goes farther, following the algorithm showing in Figure 2.

```
PLAYERS'-PAYOFFS
j = 1
for i = 1 to 3
      if P[i] = Ball
          if payoff for P[i] ≥ 1
              while j ≤ 3 and P[j]s' payoffs ≥ 1
                  Pass to P[j] with higher payoff
                  j = j+1
              Pass the ball to the opponent field
          else
              Pass to P with higher payoff
```

Figure 2. General algorithm for each player to adapt a new situation

In Figure 2, we show that if any of the players ($P[i]$) is in possession of the ball, where i, and j are different players, he will examine his chances of scoring depending on our four concepts for fast adaptation. The players may interact with each other by passing the ball amongst themselves until it reaches a player who has a higher payoff or a player with a better payoff is their distance. By the time the ball reaches the player with the higher payoff, he will pass the ball to the opponent's field to have a higher chance of scoring, as demonstrated in Figure 3.

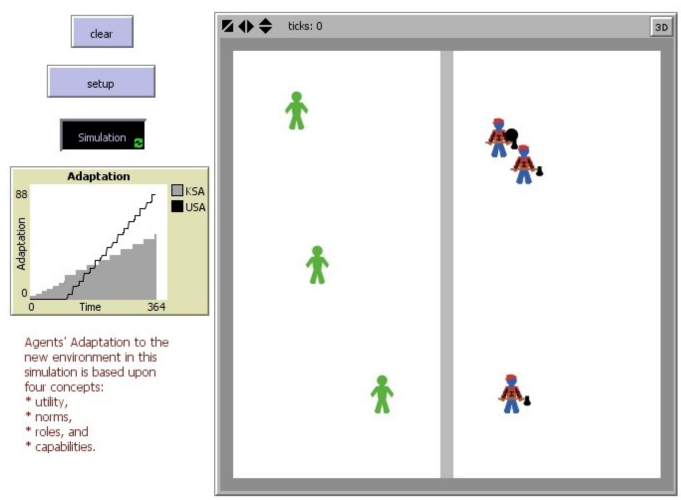

Figure 3. A screenshot of volleyball implementation after start of simulation

Any agent inside any of the small organizations (i.e., team) measures the distance between itself and the ball to check whether the ball is within its allowed distance or not; if so, the agent (i.e., the player) will move toward the ball considering itself responsible for controlling the ball and announcing that to the closest agent in order to stop him from a possible collision. When the agent controls the ball, it will measure the distance between its position and the opponent's field again to determine if there is a possibility of scoring or not, and also to measure the distance to the closest agent inside the team because the other player may have a better payoff in scoring in the opponent field than itself.

As results, the plot in Figure 3 shows that the rates of adaptation change after the agent finds any other objects (i.e., team member, or a ball) within its range, and it rises over time when any of the agents interact with them. The gray bars represent the KSA team and the black line represents the USA team. The adaptation of the KSA team starts when any of the agents recognize the ball within their proximity and it is set stable because there are no interactions occurring. However, the adaptation rises when the agent catches the ball and starts to use any of the four adaptation concepts in its move. When the agents reach similar capabilities and norms, their adaptations will increase rapidly until it reaches some threshold point where this increase plateaus. It will resume increasing periodically when they start to implement the other two concepts in their interaction (i.e., utility and roles). In contrast, adaptation will stabilize when none of the agents inside the team has any interactions whether with the ball or with other agents.

As with the previous example illustrates, implementing the four concepts of utilities, roles, capability, and norms inside an existing organization improves the performance of the members inside it in order to rapidly adapt to any new environment including any variations to in the ball and player configurations.

4 Conclusions

We have demonstrated how agents inside a specific organization may adapt to a new environment in a short period of time, and then start to interact with other agents inside the same organization. A volleyball game has been simulated in Netlogo in order to give a concrete understanding of the issue in a simple way and to make it easier to get the results out of it. Moreover, we have found that after considering the four main concepts we modeled inside the organization (utility, role, capability, and norms), agents are able to rapidly adapt to their new environment. This model (i.e. RUCN) can capably replace previous models that have been done inside any organization for the sake of fast adaptation among its members or a new environment.

5 References

[1] G. Boella, J. Hulstijn, and L. Torre, *"Virtual Organization as Normative Multiagent System,"* in the 38th Hawaii International Conference on System Science, 2005.

[2] K. Carley & L. Gasser, *"Computational organization theory,"* in Multiagent systems: A modern approach to distributed artificial intelligence, G. Weiss, Ed. Cambridge, MA: MIT Press, pp. 299–-330, 1999.

[3] C. Carrascosa, A. Giret, A. Julian, M. Rebollo, E. Argente, and V. Botti, *"Service oriented mas: An open architecture,"* in the 8th Int. Conf. on Autonomous Agents and Multiagent systems, 2009, pp. 1291-1292, ACM press.

[4] U. Chajewska, D. Koller, and D. Ormoneit, *"Learning an agent's utility function by observing behavior,"* in the Eighteenth International Conference on Machine Learning (ICML), 2001, pp. 35-42.

[5] S. DeLoach, and E. Matson, *"An organizational model for designing adaptive multiagent systems,"* in the AAAI-04 Workshop on Agent Organizations: Theory and Practice (AOTP), 2004, pp. 66-73.

[6] V. Dignum, *"A model for organizational interaction: based on agents, founded in logic,"* 2004

[7] V. Dignum, F. Dignum, V. Furtado, A. Melo, and L. Sonenberg, *"Towards a simulation tool for evaluating dynamic reorganization of agents societies,"* in WS. on Socially Inspired Computing, 2005

[8] J. Epstein, *"Generative social science: Studies in agent-based computational modeling,"* Princeton University Press, 2007.

[9] I. Foster, C. Kesselman, and S. Tuecke, *"The anatomy of the grid: Enabling scalable virtual organizations".* International Journal of Supercomputer Applications, 15, 3, 2001.

[10] S. Harmon, S. DeLoach, and Robby, *"Abstract requirement analysis in multiagent system design,"* in the IEEE/WIC/ACM International Conference on Intelligent Agent Technology (IAT '09), 2009, pp. 86-91.

[11] H. Hexmoor, *"Oversight of reorganization in massive multiagent systems";* International journal of Multiagent and Grid Systems (IMCST), 2011.

[12] D. Krackhardt, and K. Carley, *"A PCANS model of structure in organization,"* in the 1998 International Symposium on Command and Control Research and Technology, Vienna, VA: Evidence Based Research, 1998, pp. 113-119.

[13] K. Leyton-Brown, and Y. Shoham, *"Essentials of game theory: A concise multidisciplinary introduction,"* in Synthesis Lectures on Artificial Intelligence and Machine Learning,1, 2, pp. 88, 2008.

[14] E. Matson, and S. DeLoach*, "Using dynamic capability evaluation to organize a team of cooperative, autonomous robots,"* in the 2003 International Conference on Artificial Intelligence, pp. 744-749, 2003.

[15] E. Matson , and S. DeLoach, *"Formal transition in agent organizations,"* in IEEE International Conference on Knowledge Intensive Multiagent Systems (KIMAS '05), 2005.

[16] S. Rodriguez, B. Perez-Lancho, J. De Paz, J. Bajo, and J. Corchado, *"Ovamah: multiagent-based adaptive virtual organizations,"* in 12th International Conference on Information Fusion, pp. 990-997, 2009.

[17] G. Serugendo, M. Gleizes, and A. Karageorgos, *"Self-organization in multi-agent systems."* Knowl. Eng. Rev., 20, 2, pp.165-189, 2005.

[18] J. Wu, D. Sun, B. Hu, and Y. Zhang, *"Organizational adaptative behavior: The complex perspective of individuals-tasks interaction."* Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, 4, 1, pp. 28-38, 2009.

[19] Q. Zhang, and X. Zhang, *"Study of virtual organizations using multiagent,"* in the fourth international joint conference on Autonomous agents and multiagent systems AAMAS, pp. 1147, 2005.