Exploiting the Overlapping of Higher Order Entities within Multi-Agent Systems

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ABSTRACT

Currently multi-agent systems (MAS, sometimes MASs) are receiving great attention as a promising approach for modeling, designing, and developing complex, decentralized and large-scale software systems. The captivating characteristics they provide such as decentralization, dynamic reorganization, self-organization, emergence, autonomy, etc., make them a perfect solution for handling current software systems challenges specially their unpredictable and highly changing working environments. Organization-centered MAS (OCMAS) are concerned with the modeling of MAS using higher order abstraction entities than individual agents. Organizational models are the key tool to develop OCMAS; they are currently an important part of most agent-oriented software engineering (AOSE) methodologies. This paper proposes a novel organizational model called NOSHAPE. It exploits the overlapping relationships among higher order abstraction entities such as organizations of agents, worlds of organizations, and even universes of worlds within MAS to realize and utilize their captivating characteristics. The NOSHAPE model is informally and semi-formally described and its applicability is demonstrated with a case study.

Keywords: Agent-Oriented Software Engineering, Dynamic Reorganization, Multi-Agent Systems, Organizational Models, Overarchical MAS, Overlapping Exploitation, Self-Organization

1. INTRODUCTION

A MAS is formed by the collection of autonomous agents situated in a certain environment, respond to their environment dynamic changes, interact with other agents, and persist to achieve their own goals or the global system goals. Jennings and Wooldridge (2000) pointed out that considering MAS with no real structure is not suitable for handling current software systems complexity, and higher order abstractions should be used. The same meaning stated by Odell et. al (2003) that the current practice of MAS design tends to be limited to individual agents and small face-to-face groups of agents that operate as closed systems. Our real world getting more complex and highly distributed and that should be reflected in new software engineering paradigms such as MASs. So, the adoption of higher order abstract concepts like organizations, societies, communities, and groups of agents can reduce systems complexity, increase its efficiency, and improve system scalability.

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Organizations can be used to limit the scope of interactions, provide strength in numbers, reduce or manage uncertainty, reduce or explicitly increase redundancy or formalize high-level goals which no single agent may be aware of (Horling and Lesser, 2004). Shehory (1998) defined Multi-agent organization as the way in which multiple agents are organized to form a MAS, and he stated that relationships and interactions among the agents and specific roles of agents within the organization are the focus of multi-agent organization. The use of organizations provides a new way for describing the structures and the interactions that take place in MAS. Organizations provide a framework for structuring and managing agents’ interactions and serve as a kind of ‘tuning’ of the agents autonomy level (Hübner, 2009). Representing a MAS as an organization consists of roles which enacted by agents which arranged (statically or dynamically) to form groups of agents, can handle many drawbacks such as system complexity, uncertainty, and system dynamism (Ferber, 2004). The main concern of organizational models is to describe the structural and dynamical aspects of organizations (Ferber, 2005). They have proven to be a useful tool for the analysis and design of multi-agent systems. Furthermore, they provide a framework to manage and engineer organizations, dynamic reorganization, self-organization, emergence, and autonomy within multi-agent systems. Moreover, the underlying organizational model is responsible of how efficiently and effectively organizations carry out their tasks, they have been recently used in agent theory for modeling coordination in open systems and to ensure social order in multi-agent system applications (Van Den Broek, 2006). The adoption of organizational models is now a main concern of most agent-oriented software engineering methodologies. The motivation to this direction is that in open environments, agents must be able to adapt towards the most appropriate organizations according to the environment conditions and their unpredictable changes. As a result, the organizational models should guarantee the ability of organizations to dynamically reorganize as a response to dynamic environment changes.

This article proposes a novel organizational model that covers and handles all the shortcomings of other related models (see next section). The paper is organized as follows; the first section presents an introduction to the paper subject. The second section provides a study of the related work. The third section proposes a spectrum of entities relationships as a way to analysis and study MAS. The forth section presents a Meta-Model for the proposed organizational model. The fifth section describes the sources of inspiration. The sixth section provides an anatomy of the organization abstract in the proposed model. The seventh section proposes a suggested notation for describing the NOSHAPE organizational model. The eighth Section proposes a way to realize NOSHAPE. The ninth section demonstrates the applicability of NOSHAPE by presenting a Case Study project (agent-based SCADA). And finally, the tenth section concludes the paper and highlights the intended future work.

2. RELATED WORK

Many organizational models had been proposed in the MAS literature such as (Ferber, 2005; Van Den Broek, 2006; Ferber, 2004; Hoogendoorn, 2009; Mathieu, 2002; Weyns, 2010; Matson, 2005; Odell, 2005; Sultanik, 2009; Dignum, 2002; Piunti, 2010; Vázquez-Salceda, 2005; Sansores, 2008) and more others (not mentioned for the sake of paper size); we generally summarize here our notes about these models:

- Some of these organizational models tackle with organization structure issues at design time (pure static), and others tackle them at will (pure dynamic).
- In some of them the organization abstraction is not explicit and the responsibility of dynamic reorganization is given to individual agents in addition to their functional responsibilities.
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