An Agent-Oriented Software Engineering Methodology to Develop Adaptive Virtual Organizations

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Abstract

This paper presents the current state of this research work, aimed to develop a methodology for designing Adaptive Virtual Organizations. This paper includes both completed and remaining work on this topic.

1 Introduction

Agent-based software development is a trending topic of research inside the Artificial Intelligence community. There are different approaches to define a Multi-Agent System (MAS), ranging from closed, agent-centered systems to open, organization-oriented systems. In order to help designers and developers of this kind of systems, the Agent Oriented Software Engineering (AOSE [Wooldridge and Ciancarini, 2001]) community has presented a set of development methodologies and processes. These methodologies can be classified into agent-centered, like Gaia [Wooldridge *et al.*, 2000] or PASSI [Cossentino, 2005]; or organization-centered (i.e. they define Organization Centered Multi-Agent Systems, OCMAS [Lemaître and Excelente, 1998]) such as MOISE [Hubner *et al.*, 2002] or GORMAS [Argente *et al.*, 2009]. In OCMAS, agents are aware of the organization where they are participating and they are provided with a representation of it. They can use this knowledge to reason about it and to establish relationships and interactions to reach their objectives.

One of the paradigms to define OCMAS are Virtual Organizations (VOs) [Foster and Kesselman, 2001], which are sets of individuals and institutions that need to coordinate resources and services. Thus, they are open systems formed by the grouping and collaboration of heterogeneous entities, and allowing model systems at a high level of abstraction, including the integration of organizational and individual perspectives. VOs can be described by means of the Organizational Dimensions [Criado *et al.*, 2009], i.e. structural, functional, dynamical, environment and normative dimensions.

Nowadays, it seems necessary to be provided with VOs that should be able to change through time, giving an appropriate response to changes in their environment or by internal requirements. Therefore, this type of VOs, known as Adaptive VOs, is able to reorganize itself in order to maximize its capabilities and productivity. Current approaches, such as [Hubner *et al.*, 2002; Dignum *et al.*, 2005; Hoogendoorn *et al.*, 2007], normally focus on rules for reorganization. However, both internal and external forces may produce changes in the organization from a top-down or a bottom-up perspective. These changes will be given in structural (topology, roles, norms, etc.) and functional (services, objectives, etc.) elements of the organization.

The objective of this work is to build up an AOSE development methodology to design Adaptive VOs that will extend the GORMAS methodology. GORMAS defines a set of activities for the analysis and design of VOs, including the design of their organizational structure and their dynamics. With this method, all services offered and required by the VO are clearly defined, as well as its internal structure and the norms that govern its behavior.

2 Completed Research

Prior to the definition of a development methodology for Adaptive VOs it is necessary to have different mechanisms that support the adaptation process. One of the main reasons of the Organizational Change is a variation in the environment of a given organization. In order to manage this environment, it is necessary to be provided with tools that facilitate this task. For this reason, we developed the **Artifacts for Organizational Mechanisms** [Esparcia *et al.*, 2010]. They model the *Organizational Mechanisms* [Centeno *et al.*, 2009] by means of the artifacts from the *Agents & Artifacts* conceptual framework [Ricci *et al.*, 2007]. Organizational Mechanisms are introduced in a MAS with the aim of influencing the agents' behavior towards more effectiveness with regard to some goals from both a macro and a micro perspective. Hence, these mechanisms can provide additional information to agents that may persuade them to behave in a certain way; or they can produce changes in the environment that may impose certain behaviors to agents. Thus, it is very useful to use these mechanisms in an open system where external agents are located, so then being able to promote coordination.

Organizational mechanisms have been modeled as artifacts to facilitate developers to better deploy and implement them, as well as adding functionality in MAS environments. Three types of Artifacts for Organizational Mechanisms have been defined: (i) *Informative Artifacts*, which provide information to an agent based on the internal state of this agent and the partial view of the environment that the artifact has; (ii) *Incentive Artifacts*, which modify the global behavior of the

system by changing the incentive system of the MAS; and (iii) *Coercive Artifacts*, which update the action space of an agent. All these artifacts make use of the environment of a MAS, so they can exploit all knowledge they have about entities populating the system.

Additionally, a formalization for Virtual Organizations was required after noticing that state-of-the-art formalizations do not take into account all concepts from Organizational Dimensions. Therefore, we needed a proposal aimed to cover all these concepts and to provide a formalization as much complete as possible, with the aim of identifying the elements that compose a VO, facilitating the adaptation process, and checking its correctness. Therefore, we presented a formal specification for Virtual Organizations, named **Virtual Organization Formalization** (VOF) [Esparcia and Argente, 2011], which is composed by: (i) the *Organizational Specification*, which details the static components of the system and divides them by means of the organizational dimensions; (ii) the *Organizational Entity*, which defines the active elements of the system; and (iii) the *Organizational Dynamics*, which details the relationships between elements from the Organizational Specification and the Organizational Entity.

3 Future Work

This research work is focused on providing an AOSE methodology that should be able to deal with issues related to Adaptive VOs. Internal and external forces that drive change in human organizations [Aldrich, 1999] must be studied, in order to determine whether they are relevant to Adaptive VOs or not; as well as self-adaptive and self-organization concepts currently presented in different types of MAS (like [Hoogendoorn *et al.*, 2007]), comparing them with our approach. This methodology will be based on GORMAS, which will be extended by including new guidelines and patterns that support changes in an organization, in both top-down (changes decided by the organizational management) and bottom-up (organizational changes emerge from interactions between agents) approaches, in order to help developers to manage adaptation processes. Also, the Virtual Organization Model, which is the metamodel supported by GORMAS, will be extended with entities like the Artifacts for Organizational Mechanisms, and other elements that present features that will be helpful for adaptive issues. Finally, VOF will be integrated into the new methodology, helping to check the correctness of a designed Adaptive VO.

Acknowledgements

This work is supported by TIN2009-13839-C03-01, PROMETEO/2008/051 projects of the Spanish government and CONSOLIDER-INGENIO 2010 under grant CSD2007-00022.

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