Chapter IV
OMACS:
A Framework for Adaptive, Complex Systems

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ABSTRACT

This chapter introduces a suite of technologies for building complex, adaptive systems. It is based in the multi-agent systems paradigm and uses the Organization Model for Adaptive Computational Systems (OMACS). OMACS defines the knowledge needed about a system’s structure and capabilities to allow it to reorganize at runtime in the face of a changing environment and its agent’s capabilities. However, the OMACS model is only useful if it is supported by a set of methodologies, techniques, and architectures that allow it to be implemented effectively on a wide variety of systems. To this end, this chapter presents a suite of technologies including (1) the Organization-based Multiagent Systems Engineering (O-MaSE) methodology, (2) a set of policy specification techniques that allow an OMACS system to remain flexible while still providing guidance, and (3) a set of architectures and algorithms used to implement OMACS-based systems. The chapter also includes the presentation of a small OMACS-based system.

INTRODUCTION

Multiagent systems have become popular over the last few years for building complex, adaptive systems in a distributed, heterogeneous setting. The problem is that many multiagent systems are typically designed to work within a limited set of configurations. Even when the system possesses the resources and computational power to accomplish its goal, it may be constrained by its own structure and knowledge of its member’s capabilities. To overcome these problems, we have developed a framework that allows the system to design its own organization at runtime. The key component of our framework is the Organization Model for Adaptive Computational Systems (OMACS). OMACS defines the knowledge needed about a system’s structure and capabilities to allow it to reorganize at runtime in the face of a
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changing environment and its agent’s capabilities. Thus, as is also pointed out in Chapter III “Towards an Integral Approach of Organizations in Multi-Agent Systems”, by Ferber et al. the environment plays an critical role in the specification of adaptive organizations. The OMACS model is based on the assumption that agents accept certain limitations on their autonomy; if assigned a role to play in order to achieve a goal, the agents must agree to attempt to play that role in the organization and pursue the assigned goal. The OMACS model also assumes no specific architecture (although one appropriate example is presented later in the chapter). It is assumed that the “organization” reasons based on the knowledge described in OMACS.

That being said, the OMACS model is only useful if it is supported by a set of methodologies, techniques, and architectures that allow it to be implemented effectively on a wide variety of systems. To this end, this chapter also presents a suite of technologies developed to support OMACS-based system development. After discussing the OMACS model, we present the Organization-based Multiagent Systems Engineering (O-MaSE) methodology. O-MaSE is a framework for creating O-MaSE compliant processes that support the development of OMACS-based systems. Next, we discuss an area of vital importance to reorganizing systems, policy specification. Since it is often desirable to constrain how a system can reorganize, we have investigated the notion of system-level policies. In this section we introduce the notion of guidance policies that allow us to specify policies that must be followed except when absolutely necessary. Finally, we present an architecture and a set of algorithms that can be used to implement OMACS-based systems.

BACKGROUND

Computational organization theory uses mathematical and computational techniques to study both human and artificial organizations (Carley 1999). While organizational concepts are not exclusive to computational organization theory, results from the field are illuminating. Specifically, they suggest that organizations tend to adapt to increase performance or efficiency, that “the most successful organizations tend to be highly flexible” (Carley 1998), and that the best organizational designs are highly application and situation dependent (Carley, 1995). Recently, the notion of separating the agents populating a multiagent system from the system organization (Zambonelli, Jennings, & Woodridge, 2001) has become well-accepted. While agents play roles within the organization, they do not constitute the organization. The organization itself is part of the agent’s environment and defines the social setting in which the agent must exist. An organization includes organizational structures as well as policies, which define the requirements for system creation and operation.

There have been several attempts at formalizing the concepts of teamwork within an organization in the area of multiagent systems. While efforts such as Teamwork (Cohen & Levesque, 1991), Joint Intentions (Jennings, 1995), Shared Plans (Grosz & Kraus, 1996) and Planned Team Activity (Kinny, Ljungberg, Rao, Sonenberg, Tidhar & Werner, 1992), have been proposed and even implemented (Tambe, 1997), they fail to provide straightforward and easily adaptable concepts for wide spread development of such systems. In addition, these approaches require all agents to be capable of sophisticated reasoning about their organization, which tends to get intertwined with reasoning about the application, thus increasing the complexity of the agents.

While there have been several organization models proposed, none have been specifically targeted towards providing a general mechanism that allows the system to reorganize in order to adapt to its
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