Chapter VIII  
Scalable Fault Tolerant Agent Grooming Environment (SAGE)  

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ABSTRACT  

Multi-agent systems (MAS) advocate an agent-based approach to software engineering based on decomposing problems in terms of decentralized, autonomous agents that can engage in flexible, high-level interactions. This chapter introduces scalable fault tolerant agent grooming environment (SAGE), a second-generation Foundation for Intelligent Physical Agents (FIPA)-compliant multi-agent system developed at NIIT-Comtec, which provides an environment for creating distributed, intelligent, and autonomous entities that are encapsulated as agents. The chapter focuses on the highlight of SAGE, which is its decentralized fault-tolerant architecture that can be used to develop applications in a number of areas such as e-health, e-government, and e-science. In addition, SAGE architecture provides tools for runtime agent management, directory facilitation, monitoring, and editing messages exchange between agents. SAGE also provides a built-in mechanism to program agent behavior and their capabilities with the help of its autonomous agent architecture, which is the other major highlight of this chapter. The authors believe that the market for agent-based applications is growing rapidly, and SAGE can play a crucial role for future intelligent applications development.
INTRODUCTION

Multi-agent systems (MAS) are based on the idea that a cooperative working environment comprised of synergistic software components can cope with problems that are hard to solve using traditional centralized approach to computation (Jennings, 2000). Smaller software entities—software agents—with special capabilities (autonomous, reactive, pro-active, and social) are used instead to interact in a flexible and dynamic way to solve problems more efficiently.

MAS is a distributed paradigm that contains a community of social agents, which can act on behalf of their owners (Wooldridge, 2000). It is increasingly becoming an ubiquitous paradigm for the design and implementation of complex software applications as it can support distributed collaborative problem solving by having collections of agents that dynamically organize themselves. The improvements in the use of multi-agent technology in automation and manufacturing systems are fast adaptation to system reconfiguration (for example, addition or removal of resources, different organizational structures, etc.), re-use of code for other control applications, increase of flexibility and adaptation of the control application, and more optimised and modular software development.

Multi-agent systems have been developed for a variety of application domains, including electronic commerce, air traffic control, workflow management, transportation systems, and Web applications, among others. Critical importance of agent-oriented architectural concepts is being highlighted in the next-generation computing domains (Luck, McBurney, & Preist, 2002). Autonomic computing in particular views autonomic elements as agents and autonomic systems as multi-agent systems. The next-generation agent computing calls for the development of multi-agent systems developed on this very theme of autonomic computing, possessing the key characteristics of self-managing systems, namely self-healing, self-protecting, self-adapting, and self-optimising (Kephart & Chess, 2003). Our research focuses on the development of a next-generation multi-agent system called scalable fault tolerant agent grooming environment (SAGE) (Farooq Ahmad et al., 2003; Zaheer, Farooq Ahmad, Ali, & Suguri, 2005).

The vision of SAGE takes inspiration from the concept of autonomic computing, which originates directly from theoretical perspective of autonomous decentralized system (ADS) (Mori, 1993). ADS primarily relies on the principles of autonomous controllability and autonomous coordinability. These two properties assure online expansion, fault tolerance, and online maintenance of the system. They suggest that every “autonomous” subsystem requires an intelligence to manage itself and without directing to and being directed from the other subsystems and to coordinate with other subsystems. Based on this notion of ADS, each component of the multi-agent system is conceived to exhibit its own autonomic behavior, contributing to the overall autonomic behavior of the system (McCann & Huebscher, 2004). Particularly at the level of individual components of an MAS, well-established techniques, many of which fall under the rubric of fault tolerance, have led to the development of elements that rarely fail, which is one important aspect of being autonomic (Kephart & Chess, 2003). We describe below how we envision SAGE, as primarily a fault-tolerant agent environment complemented by well-defined agent architecture to facilitate the development of agent-based applications.

Twofold Approach Toward Next-Generation Computing

Autonomic computing is seen as a holistic vision that enables a computing system to “deliver much more automation than the sum of its individually self-managed parts” by various researchers (Koehler, Giblin, Gantenbein, & Hauser, 2003). Autonomic computing systems ought to self-con-
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