Chapter 11
Multi-Agent Systems for the Application and Employing of E-Health Services

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ABSTRACT

Multi-agent systems have been importantly contributing to the development of the theory and the practice of complex distributed systems and, in particular, have shown the potential to meet critical needs in high-speed, mission-critical content-rich and distributed information applications where mutual interdependencies, dynamic environments, uncertainty, and sophisticated control play a role. Therefore, multi-agent systems can be considered a suitable technology for the realization of healthcare applications where the use of loosely coupled and heterogeneous components, the dynamic and distributed management of data and the remote collaboration among users are often the most relevant requirements.

INTRODUCTION

Multi-agent systems are one of the most interesting areas in software research and they have been importantly contributing to the development of the theory and the practice of complex distributed systems (see, e.g., Jennings et al., 1995; Muller, 1998; Bordini et al., 2005) and, in particular, have shown the potential to meet critical needs in high-speed, mission-critical content-rich and distributed information systems where mutual interdependencies, dynamic environments, uncertainty, and sophisticated control play a role (Gasser, 2001). Healthcare applications can take outstanding advantage of the intrinsic characteristics of multi-agent systems because of notable features that most healthcare applications share: *(i)* they are composed of loosely coupled (complex) systems; *(ii)* they are realized in terms of heterogeneous components and legacy systems; *(iii)* they dynamically manage distributed data and resources; and *(iv)* they are often accessed by remote users in (synchronous) collaboration (Moreno & Nealon, 2003; Annicchiarico et al., 2008).

The goal of this chapter is to describe the main reasons why multi-agent systems are considered one of the most interesting technologies for the

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development of healthcare applications and services. It provides some guidelines intended to help identifying the kinds of healthcare applications that can truly take advantage of the features of multi-agent systems, and it presents some of the most important international projects that used multi-agent systems in the healthcare domain.

BACKGROUND

Agent and *multi-agent system* are terms that found their way into a number of technologies and they have been largely used in, e.g., Artificial Intelligence, Databases, Operating Systems and Computer Networks. Although there is no such thing as an accepted definition of an agent (see, e.g., Genesereth & Ketchpel, 1994; Wooldridge & Jennings, 1995; Russell & Norvig, 2003), all definitions agree that an agent is essentially an autonomous software entity that provides an interoperable interface and that behaves like a rational actor working on behalf of some client in pursuit of its own agenda. Agents are designed to operate in dynamic and uncertain environments, making complex decisions at run-time, and the learning capabilities of some kinds of agents make them able to improve their performances over time, thus avoiding repeated negative conditions and persisting on successful behaviours.

Even if a complex system can be based on a solitary agent working within its environment–that may or may not comprise users–usually agent-based systems are realized in terms of multiple, interacting agents, i.e., agent-based systems are normally multi-agent systems.

Multi-agent systems are generally considered an appropriate means for modelling complex, distributed systems, even if such a multiplicity naturally introduces the possibility of having different agents with potentially conflicting goals. Agents may decide to cooperate for mutual benefit, or they may compete to serve their own interests. Agents take advantage of their social ability to exhibit flexible coordination behaviours that make them able to both cooperate in the achievement of shared goals or to compete on the acquisition of resources and tasks. Agents have the ability of coordinating their behaviours into coherent global actions. Coordination among agents can be handled with a variety of approaches including, negotiation, contracting, organizational structuring and multi-agent planning.

Negotiation is the communication process of a group of agents in order to reach a mutually accepted agreement on some matter (Jennings, 2001). Negotiation can be competitive or cooperative depending on the behaviour of the agents involved. Competitive negotiation is used in situations where agents have independent goals that interfere. Agents are never a-priori cooperative–sharing information or willing to back down for the greater good–rather they are always somehow competitive. Cooperative negotiation is used in situations where agents have a common goal to achieve or a shared task to execute. Among the negotiation techniques, contracting is probably the best way for searching the most appropriate agent that could execute a desired task. Contracting is a negotiation technique based on a decentralized market structure where agents can take on two roles, i.e., manager and contractor, and where managers try to assign tasks to the most appropriate contractors (Smith & Davis, 1980). The basic premise of this form of coordination is that, if an agent cannot solve an assigned problem using local resources/expertise, it would decompose the problem into sub-problems and it would try to find other agents with the necessary resources/expertise to solve such sub-problems. The difficulty of assigning sub-problems is addressed by a contracting mechanism consisting of: *(i)* contract announcement by the manager agent; *(ii)* submission of bids by contracting agents in response to the announcement; and *(iii)* evaluation of the submitted bids by the contractor, which leads to awarding a sub-problem to the contractor(s) with the most appropriate bids.