Chapter 4.9
Coordinating Agent Interactions Under Open Environments

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ABSTRACT

An intelligent agent is a reactive, proactive, autonomous, and social entity. The social ability of an agent is exercised in a multi-agent system (MAS), which constitutes a collection of such agents. Current multi-agent systems mostly work in complex, open, and dynamic environments. In an open environment, many facts, such as domain constraints, agent number, and agent relationships, are not fixed. That brings a lot of difficulties to coordinate agents' interactions and cooperation. One major problem that impedes agent interaction is that most current agent interaction protocols are not very suitable for open environments. In this chapter, we introduce an approach to ameliorate agent interactions from two perspectives. First, the approach can enable agents to form knowledge "rich" interaction protocols by using ontologies. Second, we use coloured Petri net (CPN) based methods to enable agents to form interaction protocols dynamically, which are more suitable for agent interaction under open environments.

INTRODUCTION

It is beyond dispute that multi-agent systems are one of the most important design concepts for today's software. A multi-agent system (MAS) is a computational system that constitutes a collection of intelligent agents. An intelligent agent is a reactive, proactive, autonomous, and social entity, which performs a given task using information gleaned from its environment. In general, intelligent agents possess four major properties (Rao & Georgeff, 1992):

- **Reactivity**—agents can perceive their environment and respond in a timely fashion to changes that occur in it;

- **Pro-activity**—agents not only can simply act in response to their environments, but also are able to exhibit goal-directed behaviours by taking the initiative;
- **Autonomy**—agents have some level of self-control ability, and they can operate without the direct intervention of humans; and
- **Social ability**—agents interact with other agents.

The social ability of an agent is exercised in an MAS. An MAS can be considered as a society of agents that live and work together. In such a multi-agent society, interactions between agents are unavoidable (Lesser, 1999). The interaction between agents occurs when an agent has some intentions and has decided to satisfy these through influencing other agents. Agent interactions are established through exchanging messages that specify the desired performatives of other agents and declarative representations of the contents of messages.

The messages exchanged among agents are composed in agent communication languages (ACLs), such as Knowledge Query and Manipulation Language (KQML) (Finin, Labrou, & Mayfield, 1997) and the Foundation for Intelligent Physical Agents (FIPA) ACL (FIPA, 2004). In addition, messages exchanged between agents need to follow some standard patterns, which are described in agent interaction protocols (Cranefield, Purvis, Nowostawski, & Hwang, 2002). As the application domains of MASs are getting more and more complex, many current agent interaction protocols exhibit some limitations that impede MAS implementations. Firstly, many current application domains of MASs require agents to work in changing and uncertain (open) environments. In such environments, interactions between agents may be influenced by some unexpected factors, such as unexpected messages, loss of messages, or deviation in the message order. Most current agent interaction protocols lack mechanisms to handle these unexpected factors. Secondly, agent

architectures in some MASs are heterogeneous, and different agents may possess different interaction protocols. Therefore, due to the heterogeneity, when an agent initialises an interaction with others, it cannot guarantee that its interaction protocol can be understood and accepted by other agents. Thirdly, most agents are hard-coded using interaction protocols, which leads to problems. More specifically, issues such as when to use a particular protocol, what information to transmit, what order to execute tasks, and so on, are left to agent designers. This feature reduces the flexibility of the agent interactions because protocols are hard to modify at runtime once they are pre-coded into the agents. Finally, many current interaction protocols, such as KQML, are not specifically designed to carry knowledge. This kind of knowledge "poor" (Lesser, 1998) protocol is not suitable for applications that need to exchange complex knowledge. In other words, lack of flexibility and robustness of many current interaction protocols greatly limits the implementation of MASs. Accordingly, how to build a flexible and knowledge "rich" interaction protocol has become one of the main research issues in the area of MASs.

To address some of the above limitations, in this chapter we introduce an approach for agent interactions that can ameliorate agent interactions from two perspectives. First, the approach can enable agents to form knowledge "rich" interaction protocols. Toward this objective, we use ontologies to represent knowledge of agents and ontology facilitators to assist agents to search, acquire, and generate ontologies. Second, we develop a coloured Petri net (CPN) based approach to enable agents to form interaction protocols dynamically, which means protocols are not hard-coded within agents but generated by agents according to their capabilities and status.

The remainder of the chapter is arranged as follows. In the second section, we present the concept of ontologies, the formal expressions of ontologies, and the general framework for ontology-based MASs. Basic descriptions of

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