Flexible Negotiation Modeling by Using Colored Petri Nets

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ABSTRACT

In multi-agent systems, negotiations are important activities for solving agent conflicts and forming agent cooperation. Nowadays, many applications require multi-agent systems to work in open and dynamic environments. In such working environments, agents need to face various changeable factors in negotiations The dynamic features of open environments make the need of a flexible mechanism to handle agent negotiations that can involve various negotiation protocols and to allow agents to form dynamic negotiation relationships. In this article, we bring some advantages of Colored Petri Net techniques to capture dynamic and concurrent features of agent negotiations, and propose a Colored Petri Net based approach to model and handle agent negotiation activities. In this approach, agents can choose different protocols, which are represented in Colored Petri Net models, to operate negotiations. In addition, this approach supports flexible negotiations that involve different number of negotiation partners. [Article copies are available for purchase from InfoSci-on-Demand.com]

Keywords: *Business Intelligence; Colored Petri Net; Modeling Language; Multi-Agent System; Negotiation*

INTRODUCTION

Nowadays, multi-agent system (MAS) is one of the most important concepts in both artificial intelligence (AI) and the mainstream of computer science (CS). It promises a new paradigm for conceptualizing, designing and implementing software systems. In multi-agent systems (MASs), negotiations are necessary activities that can solve agent conflicts, allocate resources and form agent cooperation. As the application domains become more and more complex, many MASs are required today to work in

open environments. In such environments, multiple negotiations can happen concurrently, and factors including negotiation protocols, negotiation participants and market statuses are changeable.

To capture dynamic features of open environments in our research, we use Colored Petri Net (CPN) techniques (Jensen, 1992) into agent negotiation modeling. The CPN is a high-level extension of the Petri Net (PN) (Peterson, 1981). It is a system modeling tool that can provide an appropriate mathematical formalism for the description, construction and analysis of distributed and concurrent systems. CPNs can express a great range of interactions in graphical representations and well-defined semantics, and allow formal analysis and transformations. CPN is considered as one of the best modeling tool for concurrent systems and interactions. By using CPNs to model agent negotiations, negotiation protocols can be separated from agents. In addition, agents can be linked together and form negotiation relations flexibly. Therefore, through hiring CPN techniques, the flexibility, extensibility and robustness of MAS negotiations can be improved. In this article, we propose a CPN based approach for flexible agent negotiations. In this approach, we use CPN models to represent agent negotiation protocols. Then, agents form and operate negotiations through interacting with CPN models. Through this way, negotiation protocols are separated from agents and shared by various agents, and agents can form or join a negotiation according to their demands.

The rest of this article is arranged as follows. In Section 2, some related works of agent negotiation modeling and CPN-based approaches in agent interactions are presented. In Section 3, we briefly present related concepts of CPNs. In Section 4, we present how to use CPN models to represent agent negotiation protocols and an example to demonstrate the modeling procedures. After that, the CPN based approach that can enable flexible agent negotiations will be proposed in Section 5. In Section 6, we discuss the advantages of using CPN-based methods in agent negotiation modeling and compare them with some other modeling techniques. Finally, the conclusions and future work of the research are presented in Section 7.

RELATED WORK

Research on agent negotiation modeling has primarily focused on the description of negotiation protocols. The negotiation protocol determines the rule that participants need to follow and the flow of message among them (Bartolini et al., 2005). In an e-marketplace, various negotiation protocols could be used, which include one-to-one, one-to-many, many-to-many or concurrent protocols. For automated negotiation, agents should be able to understand and adopt a protocol according to their needs. Therefore, models of negotiation protocols should be machine-readable (i.e. allow agents to read, understand and evaluate), flexible and extensible.

Badica et al. (2005) focus on the use of UML-based descriptions of agent-based systems, and propose UML models of agent interactions in E-Commerce applications. The UML models proposed by Badica et al. can describe agent interactions clearly. However, a major shortcoming UML models is the lack of formal descriptions. Namely, agents cannot read and understand a UML model directly. Hence, additional formal annotation is required to make

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