Behavioral Modeling of Multi Agent System: High Level Petri Net Based Approach

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ABSTRACT

Modeling interactions between agents and the Multi-Agent System (MAS) behavior based on role based collaboration among the participating agents are the key factors to design of effective MAS dynamics. In this paper, a High level Multi Agent Petri Net called HMAP has been proposed which is capable of describing, analyzing and modeling dynamics of such MAS which are characterized as asynchronous, distributed, parallel and non-deterministic agent based systems. Proposed HMAP is also effective towards modeling roles, collaborations and interactions among the heterogeneous agents in MAS environment. Moreover the HMAP is useful in formal analysis of several behavioral properties of MAS like, Reachability, Home properties, Boundedness, Liveness and Fairness. The proposed mechanism has been illustrated using a suitable case study of Medical Emergency System. Moreover, to further validate the proposed concepts of HMAP, it has been simulated using Color Petri Net based tool called CPN Tool, with some restriction.

Keywords: Agent Dynamics, Agents, Behavioral Model, High Level Petri Net, Multi Agent System

INTRODUCTION

Multi-Agent System (MAS) based computing promotes, designing and developing applications in terms of autonomous software entities (agents), situated in an environment, and that can flexibly achieve their goals by interacting with one another dynamically (Zambonelli et al., 2004). Besides autonomous nature, an agent exhibits several other crucial features including goals, capabilities, situatedness, proactive/reactiveness, knowledge driven, resource driven, event driven and heterogeneity; and which have been summarized in recent literatures (Zambonelli et al., 2004; Wooldridge et al., 2001; Biswas et al., 2008; Chatterjee et al., 2011). Also dynamicity is the inherent characteristic for MAS due to event driven nature and fea-
features like autonomous and reactivity. The initial state, knowledge and goals are set. MAS manage the things dynamically to achieve the preset goals. Coordination plays a fundamental role in MAS, since it allows agents to interact with one another in a productive way (Cabri et al., 2010). This can be achieved through the modeling of Interactions among the agents in the environment. Moreover, in MAS, each agent plays a specific set of Roles to interact with another agent or other environmental elements to achieve a pre specified goal. Further, the series of events and the responses to such events may occur dynamically in such system.

In this context an important challenge is to devise a mechanism to study the dynamic behavior of Agents in MAS at the design level. For such study and modeling of MAS behavior, it is to be ensured that, (i) system will achieve the goal with finite number of events and interactions, (ii) system will operate in deadlock-free way, as the system will be handling the resources from the environment, (iii) system and environment should transform in acceptable states with the occurrences of events and interactions, (iv) the knowledge and the state of the resources are dynamically manageable. In view of these features, Petri Net (Murata et al., 1989) based approach is obvious choice for modeling of such dynamic behavior of MAS. Such Conceptual modeling of MAS is useful to study the architectural semantics and defines the components and their inter relationship to conceptualize the environment, agent, related events and interactions.

In recent years, several research efforts (Chatterjee et al., 2011; Moldt et al., 1997; Marzougui et al., 2010; Celaya et al., 2009; Bai et al., 2004; Chainbi, 2004; Pujari et al., 2012; Perše et al., 2010; Chang, 2012; Jun et al., 2010) have been done to model and analyze the behavior of MAS using Petri Net based approach. Among them, (Chatterjee et al., 2011; Celaya et al., 2009; Chainbi, 2004; Pujari et al., 2012) are based on basic PN based approaches. However, these approaches are less expressive for large system comprising of multiple agents and with complex agent level interactions. Celaya et al. (2009) have presented some analytical methodologies for modelling and analysis of multi-agent systems. Multi-agent systems have been regarded as discrete-event dynamic systems and Petri nets are used as a modelling tool to assess properties of the system. The PN model presented is useful in studying deadlock avoidance property of a multi-agent system as well as to assess key properties of multi-agent systems. A formalism called cooperative objects supporting the principles of the object paradigm and Petri nets for the design, validation and the implementation of multi-agent systems has been proposed by Chainbi (2004) and thus it provides objects with a high level of autonomy. Thus, the property analysis facilities are provided by the Petri nets theory. Pujari et al. (2012) have discussed about multi-agent system and how this kind of system can be analyzed and designed by using Petri net. Here it has been discussed how Petri nets can be used as a modelling tool to assess the structural properties of a discrete-event dynamic system like MAS.

From past literatures, it is established that PN based approaches are powerful graphical modeling tool with firmly incorporated mathematical foundations that represent a system as a set of interacting active and passive entities. The PN model has proven as a popular tool for describing and analyzing systems that are characterized as asynchronous, distributed, parallel and non-deterministic. Thus the reasons for the popularity of PN based approaches are manifold. PNs support the representation of non-determinism and thus may be considered as a sequence of discrete events just like the system it models. PNs have the ability to model a system hierarchically. As a result an explicit representation of casual system dependencies and independencies are possible. But still there are many drawbacks that make designers to think of some other types of nets to model and analyze the complex systems (Gerogiannis et al., 1998). PNs show low manageability and legibility even for description of systems of average complexity. Very large nets will be required to represent systems of medium complexity. Explicit modeling of the flow of
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