On Analysis of Agent-Oriented Petri net

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Multi-agent systems are distributed problem solving systems in which multiple autonomous agents behave cooperatively.

One of advantages of multi-agent systems is that agents with even simple function can process complicated problems through their cooperation. In addition, they have flexibility in disturbance and changes in the situation.

Multi-agent systems is expected to have many application fields, such as flexible manufacturing systems in which robots, automated guided vehicles, assembly machines are considered as agents, and communication systems in which data is exchanged according to some protocol.

When a multi-agent systems is modeled by Petri nets, high-level Petri nets such as colored Petri nets can express behavior of the systems.

However, colored Petri nets do not have concept of objects, i.e., encapsulated data with manipulating methods.

Therefore, it is difficult to describe each agent independently in a model. This may be a problem when one intends to change a certain description of agents.

As a result, it is not easy to change the description of some agents since the environment changes accordingly and therefore description of other agents also need to be changed.

Object-oriented Petri nets and agent-oriented Petri nets are proposed in order to solve the problem of modeling such systems. In these models, a

token is considered as not only a data, but also an object that encapsulates data structure with manipulating methods. The environment and the behavior of each agent can be described independently by modeling each agent as an object token.

Therefore, these models can solve the above problem, i.e., changes in description of agents may affect to the environment and other agents.

Moreover, agent-oriented Petri nets can describe dynamic communication link among agents, and duplicattion/disappearance of agents in the model.

By the above reasones, agent-oriented Petri nets are suitable for modeling multi-agent systems within the framework of Petri nets.

PN^2(*Petri Nets in a Petri Net*) have been proposed as an elementary class of agent-oriented Petri nets.

PN^2 consists of two layers of Petri nets - the upper layer is called an environmental net, and the Petri nets in the lower layer are called agent nets which act as tokens of the environment net.

In PN^2, a token of the environmental net is described by a Petri Nets, i.e., an agent net. Firing of a transition of PN^2 occurs as a synchronization of a transition in the environment net with transitions of agent nets.

Most of existing researches on agent-oriented Petri Net like PN^2 focus on how to describe multi-agent systems by the model, and only a few of them are for the analysis. In this research, we study efficient analysis methods of PN^2.

First, we propose a reduction method of agent nets that have fewer states and show the same behavior in the environment net.

For PN^2, reachability analysis using incidence matrices is proposed, where the size of each incidence matrix is determined by multiplication of the number of states and the number of transitions of agent nets.

If the size of each agent net can be reduced, then the size of incidence matrices also become smaller, and therefore, such reachability analysis is performed more efficiently. Note that the reduction method proposed in this research is for agent nets expressed by finite state automata.

After applying the reduction method to agent nets expressed by finite state automata, next we consider transformation of PN^2 into a PN (Petri Nets consisting of one layer) with the same behavior.

There are various methods for the analysis of PN, such as checking

reachability, invariant analysis, etc. Once we transform a given PN^2 to an equivalent PN, we can make use of such existing methods.

We propose transformation methods from PN^2 to PN so that the existing analysis methods of PN can be applied.