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Chapter XIII

Multi-Level Modeling of Multi-Mobile Agent Systems

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Abstract

This chapter deals with the modeling of mobile agent systems evolving within structured environments using a multi-level Petri net-based formalism, called n-LNS. In a n-LNS model the tokens of a net can be symbols or other nets allowing representing the behaviour of mobile entities. The chapter introduces the formal definition of n-LNS and its application to the modeling of various kinds of discrete event systems, namely batch manufacturing systems, mobile robot communities, urban traffic micro-simulation, and software agents for e-commerce. A case study is included regarding the coordination of an e-market place.

Introduction

Nowadays, organisations and processes operate supported by computer systems which are quite complex because of their largeness and versatility of the provided services. Furthermore, functioning requirements may change often.

The proposed solutions for addressing the design of these distributed systems take advantage of object-oriented methodologies allowing modularity and software reutilisation. This requires concurrent processing which is distributed among several networked computers.

In the last few years, the multi-agent systems (MAS) paradigm has been adopted for developing distributed systems (Ferber, 1999). Agent-based technology has been welcome with a great interest of many research groups because it is a promising approach for conceiving software systems applied in e-commerce, information retrieval, and manufacturing systems automation. MAS appears in these kinds of problems in which some agents have the ability to displace within the computer network; they are called mobile agents (DiMarzo, 1998; Milojicic, 1999).

For these kinds of systems, formal methods are useful for specifying and verifying the functioning of MAS during the earliest stages of the development life cycle. For this purpose Petri nets (PN) and their extensions have been widely used in software systems development because these formalisms allow representation in a clear and compact manner complex behaviour including concurrence, synchronization, resource allocation, and information exchange; particularly, in MAS, high-level PNs have been adopted for modeling partially the behaviour of agents.

In Moldt (1997), coloured PN (CPN) were used for modeling MAS; however, it is difficult to describe important elements such as the environment where the agents evolve or the agents mobility. In order to cope with these problems, a CPN extension was proposed for specifying MAS (Xu, 2000); in this work, the agent mobility is modeled through the updating of references. This approach brings the specification near to software implementation despite the loss of clearness of the description.

Recently, the approach of "nets within nets" has been held in several works for modeling systems with mobile entities. In Valk (1998), a two-level elemental object system (EOS) is proposed; the first level model is a PN state machine while tokens may be ordinary PN or integers.

Holding the same notion of nets within nets, in Hiraishi (2000) PN^2, a two-level formalism similar to the Valk's definition, is proposed; also, in Lomazova (2000), nested PN is proposed; at the same time, in Kummer (2001) and Kölher (2001), reference nets as a support of a simulation tool in which the tokens are references to other nets are proposed.

Following this approach, EOS has been extended; a less restrictive definition of a three-level net formalism for the modeling of mobile physical agents has been proposed (Almeyda, 2002). Later, this definition has been extended; a multi-level PN system, nLNS, was proposed (Villanueva, 2003; Sánchez, 2004), where an arbitrary number of levels can be defined. Also, we added a more complete interaction mechanism allowing the description of conversations among agents.

In this chapter, we present the definition of nLNS and a methodology for modeling mobile agent-based systems. The methodology is outlined and illustrated through a case study from the field of e-commerce.

The remainder of this chapter is organized as follows: the next section presents the definition of the multi-level system. Then, there is an overview of the application of n-LNS to the modeling of various systems including mobile entities. The next section illustrates the application of the proposed formalism to a case study regarding an electronic marketplace. Finally, implementation issues using the JADE framework are briefly discussed.