Abstract. This paper has three purposes. First, it presents an approach to designing an agent based on communication and organization. We will show that this approach differs from most known in the DAI field. The underlying concepts of an agent have been identified from our study of cooperation in multi-agent systems. These concepts consist of communication concepts and organization concepts. The second objective of this paper is to show the application of labeled transition systems to deal with the behavioural semantics of a multi-agent system. An agent state is described by a triplet including beliefs, goals as communication concepts and roles as organization concepts. A transition consists of an execution step in the life-cycle of an agent. Third, we use the proposed semantics to define a formal specification language which is a first-order, multi-modal, linear-time logic. We illustrate our work with the well known prey/predator problem.

1 Introduction

The recent years have witnessed a large interest in agent-oriented approaches to developing systems. While an AI system represents a human being carrying out a task which needs knowledge, experience and a certain dose of reasoning, a DAI system is designed as a "society" of agents working together to achieve a global goal. The conception of multi-agent systems cover many meanings each referring to a peculiar trend in research. These trends can be grouped in two standpoints: The first point of view can be qualified by individual conception. It gathers all researchers who think that the solution goes only through the formal representation of an agent model [1] (agents as intentional systems). Accordingly, this consists in formalizing the mental state of an agent (its beliefs, its desires, its intentions ...). Most researchers work along those lines. For example, Shoham [2], Georgeff and Rao [3], Cohen and Levesque [4], Jennings and Wooldridge [5]. In our opinion, the proposed theories mask cooperation which is one of the main forces of multi-agent systems: we have the impression that their agents are isolated. The second point of view is qualified by mass\textsuperscript{1} conception. It

\textsuperscript{1} This term was used by Ferber in [1]

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gathers people who consider that we should first think about interaction, then deduce the intentional structure of the agents and not the contrary. Our approach is in keeping with the latter standpoint. Indeed, starting from the study of cooperation in multi-agent systems [6], we identify the underlying concepts of an agent. These concepts consist of communication concepts and organization concepts. Communication in multi-agent systems as for human beings, is the basis of interaction and social organization. Communication consists of a set of psychological and physical processes relating the sender to the addressee(s) in order to reach some goals [12]. An organizational model defines how to dispatch the tasks between cooperative agents and their possible relations.

With respect to semantic models associated with multi-agent systems, two tendencies can be mentioned: a tendency toward Petri nets and a tendency toward logic. Previously, Chainbi [7] has used cooperative objects (a formalism which combines Petri nets and an object oriented approach) to model multi-agent systems. The combination between the two approaches has given a great deal of flexibility to the system structuring. This flexibility is basically due to the advantages of the object oriented approach. Unfortunately, cooperative objects have a weak analytic power. Purvis [8] try to use colored Petri nets to model multi-agent systems but the proposed model remains at a high abstraction level. The other models use formalisms associated with logical systems including Cohen & Levesque [4], Rao & Georgeff [3]. Their models are based on a possible world semantics where an agent’s beliefs, knowledge, goals, and so on, are characterized as a set of so-called possible worlds, with an accessibility relation holding between them [5]. These models suffer from some drawbacks, notably the omniscience problem which implies that an agent has unlimited resources. In this paper, we exploit another formalism which doesn’t belong to the aforementioned tendencies to deal with the behavioural aspect of a multi-agent system: labeled transition systems which have been initially introduced to define the semantics of parallel systems. The proposed semantics is the basis for the definition of a formal specification language which is a first-order, multi-modal and linear-time logic.

This paper is organized as follows: Section 2 presents a preliminary in which we give some first-order notations. Section 3 describes the model: its static and dynamic parts. This section shows also the way we have used transition systems to model multi-agent systems. Section 4 presents a specification language \( \mathcal{L}_w \) for the agent model.

2 Preliminary

In this section, we introduce some useful definitions for the formal specifications described below. These definitions deal with first-order logic.

Definition 2.1 [Signature]

Let \( N \) be the set of positive integers. A signature is a set \( \Sigma \) of function and constant symbols with a function \( ar : \Sigma \longrightarrow N \). If \( f \in \Sigma \) and