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An ontology-based metamodel for multiagent-based simulations

Florian Béhé [a,b], Stéphane Galland [a,*], Nicolas Gaud [a], Christophe Nicolle [b], Abderrafiaa Koukam [a]

[a] Multiagent Group, IRTES-SET, Université de Technologie de Belfort-Montbéliard, Belfort, France[1]
[b] CheckSem Project, LE2I-CNRS, Université de Bourgogne, Dijon, France[2]

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ABSTRACT

Multiagent-based simulations enable us to validate different use-case scenarios in a lot of application domains. The idea is to develop a realistic virtual environment to test particular domain-specific procedures. This paper presents our general framework for interactive multiagent-based simulations in virtual environments. The major contribution of this paper is the integration of the notion of ontology as a core element to the design process of a behavioral simulation. The proposed metamodel describes the concepts of a multiagent simulation using situated agents moving in a semantically enriched 3D environment. The agents perceive the geometric and semantic data in the surrounding environment. They are also able to act in this environment by using high-level actions, which are described by the ontology of the environment. The concepts relating to the environment, the agent, and the entire simulation models are presented. Additionally, guidelines are given to exploit the simulation results to characterize the agents. Finally, a simple application of the metamodel is presented, based upon the use of Industry Foundation Classes.

1. Introduction

Multiagent-based simulations are now a common tool in various application domains to assess/validate different use-case scenarios: social sciences, urban management, transport, building security assessment, etc. The idea is to develop a realistic virtual environment to test particular domain-specific procedures. Developing realistic scenarios implies that they must be non-deterministic and agents inhabiting virtual environments are autonomous and intelligent. The variety of their behavior must reflect the heterogeneity of human behavior.

This paper presents our general framework for interactive multiagent-based simulations in a virtual environment (2D or 3D). Its main objective is to integrate the notion of ontology as a core element of the design process of a behavioral simulation in order to facilitate its use/reuse by simulation designers and end-users in many application fields. To ease the use of a multi-agent simulation, it should be easily configurable: each agent behavior must be at high level and application-independent, and have their configurations as automated as possible. For empirical studies, multiagent-based simulation results are generally integrated and compared with results from other types of simulation (discrete events, finite

* Corresponding author. Tel.: +33 384583418; fax: +33 384583342.
E-mail addresses: florian.behe@utbm.fr, florian.behe@checksem.fr (F. Béhé), stephane.galland@utbm.fr (S. Galland), nicolas.gaud@utbm.fr (N. Gaud), cnicolle@u-bourgogne.fr (C. Nicolle), abder.koukam@utbm.fr (Abderrafiaa Koukam).

[1] http://www.multiagent.fr.
[2] http://www.checksem.fr.

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elements, etc.) to merge the different views available on the studied system. It is therefore interesting to have a common representation of the simulation results that is both interoperable and cross-domain.

We consider that the key point to address these issues is to have a semantic description of the environment in a multi-agent-based simulation (MABS). To do this, this paper presents a new approach coupling multi-agent systems and semantic modeling with ontology.

Ontology is a general term for a semantic modeling of knowledge to define the know-how. Using ontologies, the system can infer new knowledge and relations from existing resources.

To enable the development of high-level easy to configure agent behavior, it is important to provide agents with the means to reason on their surrounding environment. The agents must be able to analyze unexpected situations to dynamically adapt their behavior to achieve their personal goals [5]. Semantic rules and the agent's reasoning procedures can enable the development of such smart behavior.

For example, if you plan to send an agent to the restaurant, just specify that your agent is hungry. With semantic rules, the agent decides that he must eat. This action is semantically linked with "restaurant" (place where agents can eat in the ontology) and then he will go, in the environment, in a place defined as a restaurant. This solution saves a lot of designing and configuration time by just modeling the agent as hungry instead of designing a whole behavioral plan. The plan is dynamically determined at runtime according to a succession of semantic rules.

The designing of the agents behaviors is thus simplified thanks to the usage of semantic. But to enable this kind of reasoning behavior, the environment must provide agents with a semantic description of themselves.

Reasoning mechanisms and dynamic adaptation procedures of agents behavior are out of the scope of this paper. In this article, we describe the essential components that must provide the environment of a multiagent-based simulation to allow agents to easily support these mechanisms. This paper presents a new metamodel for MABS exploiting situated agents evolving in a semantically enriched 3D environment. This metamodel can be considered as a generic ontology [20].

The proposed approach is illustrated on a simple example derived from typical use cases in the field of building qualification (which is one of our main targeted application areas) [3,1,4]. In this example, environment description is based on IFC (Industry Foundation Classes) files, which are a standard in the building industry.

They describe buildings in both a geometrical and semantic manner. This semantic description allows to easily build the semantic structure of the simulation environment.

The essence of our proposal is an ontology describing the semantic of every element needed or produced during a simulation (agents, environment, interactions, etc.) This ontology integrates the common MABS standards like the influences/reactions model [21,16,17,8], the clear separation between an agent's mind and body, etc. This paper presents a formal modeling of this semantic metamodel that includes the main simulation principles, how to represent agents, manage their interactions, etc.

The paper is organized as follows: after a quick introduction to your ontology-based and agent-oriented metamodel (Section 2), the different components of the proposed metamodel are successively detailed (Section 3–6). It is then illustrated on a simple scenario in Section 7. Section 8 describes related works. Finally, Section 9 summarises the contributions of the paper and describes some future work directions.

2. A quick overview of the ontology-based metamodel

The goal of our metamodel is to integrate every key element required for developing multiagent-based simulations. It is now widely recognized that a MABS may be split into at least four main parts [14,16,17]:

- **Agent behavior**: modeling of the agent's deliberative process.
- **Environment**: definition of the various physical objects composing the simulated world as well as the endogenous dynamics of the environment. It is here that a number of fundamental principles must be respected to guarantee a simulation with the least possible bias: Influence/Reaction Model, respect the environmental integrity constraint, respect the constraint of locality, clear distinction between the agent's mind (variables under the sole control of the agent, i.e.: goals, motivations, etc.) belonging to the previous part of a MABS and the agent's body (state variables of the agent's physical component not controlled by the agent, i.e.: velocity, position, etc.) belonging to the environment.
- **Scheduling**: modeling the passage of time and defining the chosen scheduling model.
- **Interactions**: modeling the result of the agents' actions and interactions.

What is considered as agent or environment obviously depends on the problem considered. The agents represent the active components of the problem we seek to study.

Our approach splits the description of a simulation into two main ontological aspects:

- **Running ontology**: describing all entities related to and produced by a simulation. This ontology describes in an anonymous manner every kind of data that is used and produced during a simulation. Instances in this ontology are not related to a specific concept like traditional ontologies but only to a high generic concept (such as "owl:Thing"). By solely having this aspect of the description, it is impossible to differentiate the nature of an object from another. An example of this ontology is available in Fig. 1. This ontology is designed to be used closely to the definition bases.