An Agent-Based Model Formalization to Support Distributed Execution

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Agent-Based Modeling (ABM) is becoming a common computational paradigm among simulation techniques [1]. The need of large scale and robust experimental results quickly arise the need of distributed execution, since the problems are inherently computationally hard and an exhaustive search is infeasible compared to the analytical approaches.

Many studies have been conducted in the field of formalization of agent-based models: the number of existing ABM description languages and tools is countless. Since there is no standard protocol for describing simulations so far (however, researchers place a considerable emphasis on establishing it [2]), nearly every software tool that supports ABM development has it's own model description dialect. As their purpose, their level of formalism differs as well, but many of them shares a common drawback: these are somehow bounded for the sequential implementation of the model, thus cannot be used for describing distributed simulations.

There are formalisms, however, that use a high abstraction level. Some model describing protocols follow a semi-formal way, like the ODD (Overview-Design-Details) protocol [2]. It contains three blocks subdivided into seven sections to help researchers improve their models and increase their scientific credibility. Its main goal is to be the first step for establishing a detailed common format of ABM, that is once initiated, will hopefully evolve as it becomes used by a sufficient proportion of modelers. This protocol describes the model mainly verbally, but contains formal components for specific parts, e.g. suggests the using of UML to specify static structure, or mathematical formalism to declare the dynamics of agents (since the interaction patterns are complex and unambiguity may be avoided). Design patterns - static model descriptions - for agent-based modeling are also available [3]. There are absolutely formal model descriptions as well (like [5]), and even programming languages exist where the language tries to replace the formalism [4].

In this paper we introduce a minimal, abstract formalization of ABMs that aggregates the advantages of the existing model definition approaches. A formalization, that is independent from programming languages, but capable to describe the agent-based models' semantics: the agents (such as state variables, initial state, and behavior), the environment of the agents (the "global" state variables), and model dynamics (agent activities and other events). We describe an algorithm that transforms this high-level description into a distributed program, and plan to conduct extended experiments and further researches, using the formalism reported herein.

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