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Validation of an agent based model using a participatory simulation gaming approach: The case of city logistics ☆

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ABSTRACT

Agent-based modeling is used for simulating the actions and interactions of autonomous entities aiming to assessing their effects on the system as a whole. At an abstract level, an agent-based model (ABM) is a representation of the many simple agents and interactions among them. The decision making of the agents is based on the rules given to them. In an ABM, the model output is the result of internal decision-making and may differ with alteration in the decision path. On the contrary, with the set of rules embedded in agents, their behavior is modeled to take a 'certain action' in a 'certain situation'. It suggests that the internal decision making behavior of agents is truly responsible for the model output and thus it cannot be ignored while validating ABMs. This research article focuses on the validating agents' behavior by evaluating decision-making processes of agents. For this purpose, we propose a validation framework based on a participatory simulation game. Using this framework we engage a human player (i.e. a domain stakeholder) to allow us to collect information about choices and validate the behavior of an individual agent. A proof-of-concept game is developed for a city logistics ABM to test the framework.

1. Introduction and motivation

Agent-based modeling is a promising alternative when traditional techniques reach its limitations. For instance, using classical optimization technique one can find a solution where a system (e.g. city logistics) can work in the most efficient way. However, when the stakeholders of the system are independent, they give priority to their personal objectives (e.g. profit, efficiency) even at the expense of system efficiency. In such situations, global optimization becomes a benchmark instead of a practice. An ABM can be designed for such system where each agent is optimizing its own goal. Such a model can be used as a laboratory where the system parameters of the model can be varied in such a way that system output goes in the direction of the global optimum, even though, the agents are taking decisions to optimize personal well-being.

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Agent-based modeling is used for simulating the actions and interactions of autonomous entities aiming to assessing their effects on the system as a whole. It combines elements of game theory, complex systems, emergence, computational sociology, and evolutionary programming (Bonabeau, 2002). At an abstract level, an agent-based model (ABM) is a representation of the many simple agents and interactions among them. The decision making of the agents is based on the rules given to them. These rules guides them about 'what to do' and 'when'. Using an ABM, a modeler can model and simulate the behavior of the system's constituent units (i.e. agents) and their interactions, capturing system level emergence from the bottom up during the simulation. Due to its ability to model a system in a natural and flexible way, an ABM can capture complex emergent behavioral patterns and gives valuable insights about the system and its activities.

At the same time, an ABM is a complex adaptive system where path dependency effect plays a critical part in driving system behavior. Such path dependent interactions give rise to unexpected patterns and consequences. Due to the path dependency of decision-making, a completely different sequence of decision-making could result in the same model output. Furthermore, the model outcome might be similar to the observed output; however, the events and/or its sequences, which lead to the model outcome, may have followed a completely different decision making path than expected. In general terms, the model output is the result of internal decision-making and may differ with alteration in the decision path. On the contrary, with the set of rules embedded in agents, their behavior is modeled to take a 'certain action' in a 'certain situation'. It suggests that the internal decision making behavior of agents is truly responsible for the model output and thus it cannot be ignored while validating ABMs. This research article focuses on the validating agents' behavior by evaluating decision-making processes of agents.

The remainder of the paper is organized as following. Section 2 gives overview about ABM validation literature. Section 3 introduces the participatory simulation gaming framework for validation of an ABM. Section 4 describes a proof of concept game explaining the game setting and the decisions taken by the game players. Section 5 discusses the results of the game under the proposed framework. Finally, Section 6 gives conclusions, recommendations and future research directions.

2. Validation of ABM in literature

An ABM can be represented by the various activities executed by agents to reach their goals. In an ABM, agents are modeled to behave independently – similar to their real counterpart (i.e. stakeholders). Fig. 1 shows three stages for ABM validation (Ligtenberg et al., 2010).

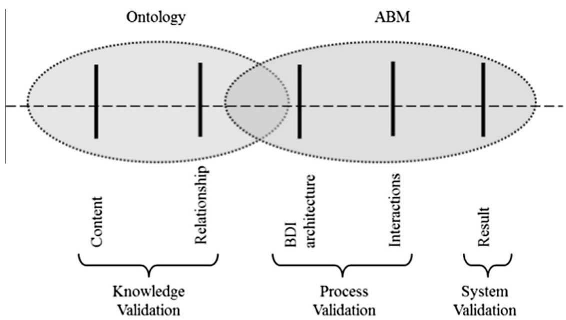

Fig. 1. Components of agent based model validation. Source: Own representation.

(1) Ontology validation: An ontology is the first step for developing an agent based model (van Dam and Lukszo, 2006; Livet et al., 2010). For a system model, the agents, their attributes and relations can be obtained in the form of the semantic information embedded in the ontological classes and relations between them. Therefore, the validation of ABM starts with the validation of the ontology, which evaluates whether the ontology represents the real world in terms of structural elements and their relationships. The field of ontology validation has been modestly explored by various researchers. Interested readers are requested to refer (Banks, 1998; Obrst et al., 2007; Anand et al., 2014a).

(2) Process validation: The relationships existing in the ontology do not vouch interactions among agents extracted from the ontology classes. For example, a shopkeeper and a shipper are related with each other; however a specific interaction of a shopkeeper complaining to a shipper does not automatically guaranteed just because they are connected. For this interaction to occur, the agent behavioral attributes and interactions must be modeled separately. Based on interaction protocols embedded in the model, the agents decide their interactions with model environment and other agents. At this stage, the ABM agents represent mainly two components – behavioral attributes and interaction protocols. To validate ABM at this level, one needs to validate the behavioral attributes and interactions of the agents with that of real world stakeholders.