An agent-oriented social simulation methodology for institutional driven evolving agents

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ABSTRACT

A comprehensive conceptualization tool for agent-based social simulation would increase the acceptance of this approach among the social scientists similar to the exiting simulation approaches such as system dynamic and discrete event modelling. In this research we explore this proposition to provide an opportunity for the social scientist to access the vast body of research in multi-agent systems area.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multiagent systems

General Terms

Design, Economics, Theory, Documentation, Languages

Keywords

agent-based social simulation, methodology, conceptualization, tool support, institutional evolution

1. MOTIVATION

With the advent of simulation platforms, more social scientists are becoming aware of the agent-based modelling and simulation approach every year. The increase in areas of application also results in larger and more sophisticated agent-based models.

Building complex agent-based models is a complex process not limited to programming. This is why many researchers provide guidelines on how to build agent-based models (e.g. [**?**]). The general steps that may be more or less refined by different scientists include model conceptualization/design, implementation, validation/verification and analysis of data. Model conceptualization as part of the process of model development is generally recognized to be an important step in building software models.

Conceptualizing a system for the purpose of simulation improves the quality of the software model, allowing modellers to better capture, analyse and understand what they are actually modelling [**?**]. Case-specific model conceptualization appears to be common practice in the ABM literature (e.g. [**?**, **?**]). Yet, a generic and formal conceptualization tool would facilitate the reuse and redevelopment of a model, while providing enhanced documentation [**?**].

In model-driven software development, a conceptual model of a system conforms to a *meta-model* which is a formal description of the set of concepts present in that system [**?**, **?**]. While there are some meta-models in the ABM and multi-agent systems (MAS) literature, they are rarely used by others specifically social scientists. There seems to be two major reasons for this.

First, the concepts provided by the current meta-models are not comprehensive enough to capture the diverse range of concepts in a social system. For example, [**?**] and [**?**] conceptualize a system with a number of entities including organization, agent, environment, task, goal and role. However, they do not address social structures such as norms and culture. Furthermore, they do not fully specify agents: agents take roles, have capabilities and goals, but they are not decision making entities with their own personal values and preferences. In their meta-model, an agent who takes a role *must* follow the role specifications and is therefore constrained in behaviour.

The second reason we see for meta-models not being used by others is that the authors provide no visual support for conceptualization and, only little guidelines on how to covert a conceptual model to executable code. On the other hand, the MAS literature which supports this process is too technical for those who do not have a background in computer science and the concepts are thus not tangible for many social scientists.

2. REQUIREMENTS FOR A COMPREHENSIVE META-MODEL

To conceptualize a social system for agent-based simulation there are two issues that need to be taken into consideration.

First, a comprehensive meta-model for the conceptualization of a social system needs to be comprehensive in terms of the coverage of social concepts.

The second issue that needs to be taken into account is the applicability and usability of the meta-model for simulation by the social scientist. The meta-model should be able to represent entities that are conceptually close to domain expert knowledge [**?**] or a social scientist modeller. Guidelines should facilitate the translation of concepts to executable code. Furthermore, modellers would highly appreciate the automation of the process of conceptualization to runnable model to whatever extent possible.

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The second issue is that the meta-model should cover as many concepts in a social system as possible. A meta-model, similar to a framework, needs to present different theories of human behaviour [**?**]. This is essential for ABM because not all problems can be answered with the same theory. For example, while some models can use rational actors, bounded rationality might be required for some other model and routine based problem solving or merely rule following actors might be sufficient for yet other models.

A meta-model for ABM requires a detailed definition of *individuals* as the key concept of a social system , their *social* and *physical* surroundings, and their operational environment. Individuals, characterized by their demographic properties, preferences, personal values, capabilities and decision making are highly influenced by the social context they are embedded in. Rules, norms, institutions and culture are in fact the necessary preconditions for individual interaction [**?**]. Nonetheless, individuals are not merely rule followers. They are intelligent entities who, based on their individual characteristics, may decide to violate rules under certain conditions.

While understanding and explaining individual behaviour is extremely complex, social rules or institutions are more elicitable [**?**]. Therefore, institutions are more feasible to identify and capture by the modellers and have the potential to be used as the basis for more complex concepts. Institution as a broadly used expression can provide a major structure for conceptualizing social systems [**?**]. The institutional analysis and development framework (IAD) is one of the institutional frameworks that provides a collection of concepts present in a social system with an institutional perspective [**?**]. Researchers have successfully used the IAD in analysing and designing social systems for many years providing a broad view of the underlying components.

3. A TOOL FOR AGENT-ORIENTED SOCIAL SIMULATION

In this thesis we base our work on the IAD framework and in fact extend and formalize its components to present a meta-model for conceptualizing social systems specifically for agent-based social simulation. We aim at addressing all the issues mentioned above in order to provide a comprehensive conceptualization tool. To facilitate the use of this meta-model which we call MAIA (*M*odelling *A*gent systems based on *I*nstitutional *A*nalysis), we propose a methodology that provides guidelines on how to produce executable code from a conceptualized model. Furthermore, we investigate how human language can be converted to formal concepts which are then turned to programming language code [**?**]. Since our tool is aimed at social scientists who are less familiar with programming, we have also implemented a web-based application that guides the conceptualization process and produces data that is used to generate java code. The semi-automated process produces code that requires minor editing to become a fully executable simulation model. The web-based application also produces tables and diagrams that are highly instrumental for documentation purposes while providing a means of communication between the team of developers as well as modellers and domain experts.

4. FURTHER CHALLENGES

Another aspect of this thesis that is currently being addressed is the implementation of institutional evolution in agent-based social simulations within the MAIA development tool. In the IAD framework, Ostrom and Crawford [**?**] provide a structure for institutional statements that covers rules, norms and shared strategies in social systems and a diversity of other social concepts. Based on this structure, we are exploring methods of institutional evolution: emergence of new institutions, extinction of old ones and update of institutions by agents.

To evaluate this research, we are testing our concepts and tools with various case studies (four case studies to date). We would also provide an evaluation framework based on a set of comparison factors to evaluate and compare this methodology with other agent-based social simulation methodologies. A evaluative survey will also be conducted to collect the feedback of the current users of MAIA.

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