Agent-based Simulation for Complex Social Systems: Support for the Developer

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Extended Abstract

The successful implementation of policies in complex social environments, require a deep understanding of interdependencies between many actors with different perspectives. In order to understand, analyse and design such complex systems, advanced modelling tools are required.

Models of many types have been extensively used for researching complex social systems. Modelling is especially suitable when prototyping or experimenting with the real system is expensive or impossible. In one extreme of the scale, text-based models are well suitable to support argumentation and decision-making by groups of people, but are not computable. On the other extreme, mathematical models, including dynamical systems, statistical models, differential equations, or game theoretic models, enable a precise and computable representation of the system, but their complexity rises exponentially as the complexity of behaviours grow, so that describing complex individual behaviour with equations often becomes an intractable task. In (Ostrom, 1988), simulation is described as a third way to represent social models, being a powerful alternative to these types. Simulation has a high descriptive power and can easily be run on a computer. Moreover, simulation can represent non-linear relationships, which are often tough problems for the mathematical approach.

In particular, Agent-Based Modelling and Simulation (ABMS) is a powerful approach for the analysis of complex social systems. This comes from the fact that agent related concepts allow the representation of organizational, social and behavioural aspects of individuals in a society and their interactions. In ABMS, system behaviour emerges as the result of the combined activity of many (tens, hundreds, thousands, millions) individuals, each following its own behaviour rules, living together in some environment and communicating with each other and with the environment. ABMS can support both qualitative and quantitative evaluation methodologies. With the advent of software platforms in recent years, agent-based modelling (ABM) has increased in popularity among social scientists (e.g. Repast (North et al., 2006), Netlogo (Tisue, 2004), Swarm (Minar, 1996)).

To aid model development, some researchers have provided guidelines on how to build agent-based models (e.g. (Gilbert and Troitzsch, 2005; Heath et al., 2009;

Drogoul et al., 2003)). The general steps that may be more or less refined by different scientists include model conceptualization/design, implementation, validation/verification, and analysis of data. Nevertheless, existing methodologies, require the modeller to possess substantial programming knowledge. Explicit model conceptualization, which entails describing the set of concepts that will constitute the "building blocks" of the model", is generally recognized to be a crucial step in building software models because it leads modellers to better capture, analyse and understand what they are actually modelling (Winograd et al., 1996). Moreover, while understanding and explaining individual behaviour is extremely complex, social rules or *institutions* are more elicitable (Scharpf, 1997) and hence more readily identified and captured by modellers. Therefore, we propose to support model development by grounding it on institutional concepts. In the social sciences, the institutional analysis and development framework (IAD) proposed by Ostrom (Ostrom, 2005) has been used successfully for many years for the conceptualization and analysis of complex social systems.

The IAD framework (cf. figure 1 focuses the analyst's attention on individuals who make decisions over some course of action. In IAD, the action arena is the unit of analysis and focus of investigation. An action situation is the "social space where individuals interact, exchange goods and services, engage in appropriation and provision activities, solve problems, or fight" (Ostrom, 2005). Policy processes and outcomes are assumed to be affected, to some degree, by four types of variables external to individuals: (1) attributes of the physical world, (2) attributes of the community within which actors are embedded, (3) rules that create incentives and constraints for certain actions, and (4) interactions with other individuals.

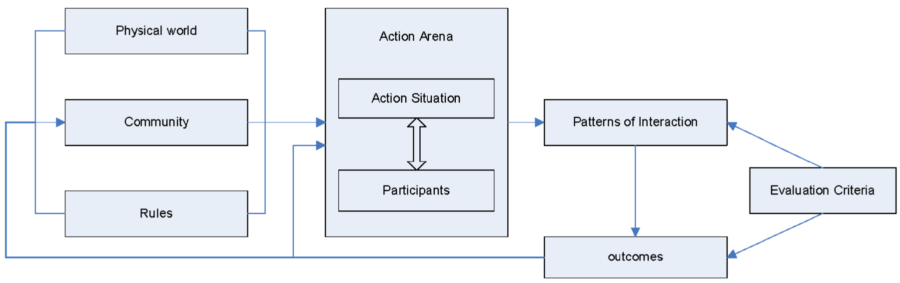

Fig. 1. The IAD framework

The IAD framework helps policy makers to organize diagnostic, analytical, and prescriptive capabilities. However, the development and use of simulations involve making precise assumptions about a limited set of variables and parameters to derive precise predictions about the results of combining these variables using a particular theory. In order to support the systematic design of agent-based simulations for complex social systems based on the IAD framework, we have developed a framework, MAIA (*M*odelling *A*gent systems based on *I*nstitutional *A*nalysis), which extends and formalizes IAD with the required modelling constructs necessary to build executable simulations.

MAIA provides an extensive set of modelling concepts rich enough to capture a large range of complex social phenomena. This set includes social concepts such as norms, culture, personal values and preferences, social roles, responsibility and dependency. The MAIA simulation package is presented in figure 2. To support the development of MAIA based models, a web-based application, takes the user through a step by step procedure, checks for consistency among the concepts and produces XML code. The user of this software application does not need any computer science background. Furthermore, MAIA provides formalized rules on the translation of social concepts to programming code, using a Model-Driven Engineering (MDE) approach that provides a transformation between the MAIA meta-model and a Java program. MDE approaches have been advocated when constructing agent-based models of social systems (Sansores and Pavón, 2005; Hassan et al., 2009; Janssen et al., 2008).

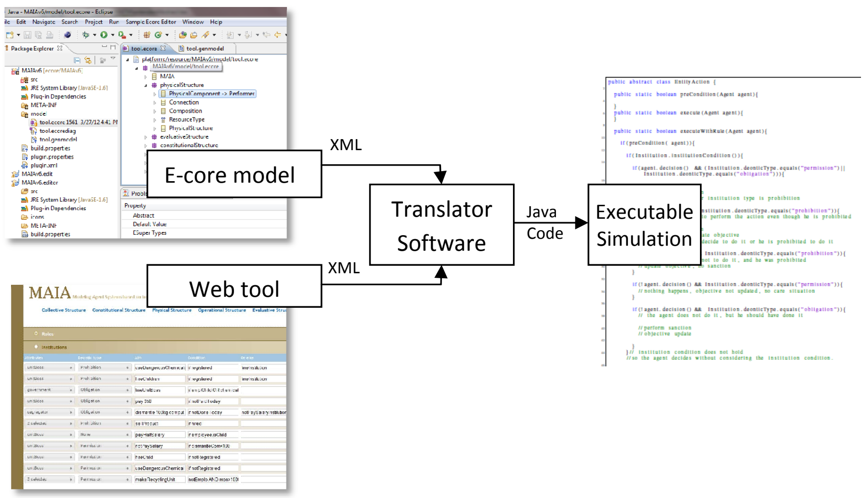

Fig. 2. The MAIA simulation package consist of a meta-model presented as an E-core specification, a web-based application to guide conceptualization and a translator code that produces executable code from a MAIA-based model.

The application of MAIA in various real world cases (consumer lighting transition (Ligtvoet et al., 2011), woodfuel market in Switzerland (Steubing et al., 2011), e-waste recycling sector in Bangalore (Ghorbani et al., 2011) and bio-gas energy production in the Netherlands) shows the usefulness of the MAIA simulation package in several aspects. First, the concepts (e.g. role, personal value) are more easy to grasp by the social scientist because they are taken from the social science theories. Furthermore, compared to other tools, because the web-based application is based on the MAIA framework, it provides a rich set of social concepts. Second, the MAIA web-based tool, appears to be efficient and reliable due to various consistency checks and automatic completion of many fields. Third, with the provided set of rules, it is theoretically and practically possible to implement a translator that automatically generates code from the set of social concepts.

Even without the use of a mediator software that would automatically generate code from the set of concepts, as we saw in our case studies, it is fairly straightforward to develop a Java program from the information provided in the web-based application. This would however, require programming knowledge. In this respect, an added value of using the tool is the possibility of having a team of modellers to develop an agent-based model: system analysts who decompose the system into MAIA concepts using the tool and do not necessarily need programming knowledge and programmers who use this information to develop a simulation program. This practice was conducted in three of our case studies. The transfer of the knowledge between the model developers was through the tool outputs.

In short, the MAIA platform supports the development of agent-based models for policy making by providing (1) a methodology that provides guidelines on how to produce executable code from a conceptualized model, (2) a web-based application that supports the conceptualization process, and (3) a (semi) automatic transformation to generate executable simulations.

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