An Overview of Multi-Agent Simulation in Organizations

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INTRODUCTION

Most economic and business systems are complex, dynamic, and non-deterministic systems. Different modeling techniques have been used for representing real life economic and business organizations either on a macro level (such as national economics) or micro level (such as business processes within a firm or strategies within an industry). Even though general computer simulation was used for modeling various systems (Zeigler, 1976) since 1970's the limitation of computer resources did not allow for in-depth simulation of dynamic social phenomena. The dynamics of social systems and impact of the behavior of individual entities in social constructs were modeled using mathematical modeling or system dynamics.

With the growing interest in multi agent systems that led to its standardization in the 1990's, multi agent systems were proposed for the use of modeling social systems (Gilbert & Conte, 1995). Multi agent simulation was able to provide a high level disintegration of the models and proper treatment of inhomogenity and individualism of the agents, thus allowing for simulation of cooperation and competition. A number of simulation models were developed in the research of biological and ecological systems such as models for testing the behavior and communication between social insects (bees and ants). Artificial systems for testing hypothesis about social order and norms as well as ancient societies (Kohler et al., 2005) were also simulated.

Since then agent based approach in economics and business has established itself as agent based social simulation (ABSS) and agent based modeling (ABM). Agent based social simulation is a multi-disciplinary approach combining agent based computing, simulation modeling and social sciences aimed at discovering different outcomes a specific social phenomena may lead to. Agent based modeling is an approach to modeling social interactions that has become an invaluable tool for understanding crucial social phenomena such as social networking and how individual behavior affects other people behavior patterns.

Numerous software toolkits have been developed, such as MASS, SeSAm, Swarm, Repast and MASON. These toolkits make agent based modeling easy enough to be attractive to practitioners from a variety of subject areas dealing with social interactions. Toolkits such as MASS make agent based modeling accessible to a large number of analysts with less programming experience.

BACKGROUND

Computer simulation modeling is an established method in scientific and industrial applications, appropriate for obtaining insight into the dynamics of organizations. Modeling is used to represent a part of reality in sufficient detail, and resulting model is an artificial system used for experimentation. There are several situations when replacement of the real system by an artificial one is helpful or even necessary.

- **Inaccessibility of the real world system:** Sometimes a part of the real world system that should be studied is not accessible either because the system does not exist any more or is not yet put into operation.
- **Real world system is inappropriate for experimentation:** Some real world systems may be affected in undesired way by experimenta-

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tion. Examining effects of drastic changes in taxing and pricing policies may e.g. disturb the fiscal system, or discourage production and consumption.

- **Time scale or behavior of the system is inappropriate for observation:** A number of systems such as investments in some industries generate results over long periods of time, making it hard to collect enough data from the real system for a meaningful analysis. Simulation is using virtual time that can be accelerated or slowed down as needed in order to observe a particular phenomenon.
- **Intensive dynamics of the system:** All elements of simulation model can be taken under full control. This is especially important in economics for the purpose of studying the impact of changes in one factor on behavior of the whole system, while holding all other factors at the same level. This presumption cannot be achieved in a real life economic system (e.g. system of supply and demand).

The model should be able to answer questions directed to the real system. However, it can produce valid output only for the set of experiments defined by the experimental frame (Zeigler, 1976) determined in the early stages of model development. After the model is successfully built, simulation experiments can be performed. In order to gain full control over the experiment, simulation model is used in predefined artificial environment and predefined virtual time of simulation.

Treatment of virtual time is crucial for selection of simulation method applied to the model.

If virtual time is *continuous* then system dynamics is used. System dynamics focuses on feedback loops of the model whose behavior is represented by differential equations. Model is restricted to macro level, and its properties are described by attributes which represent the state of the system and its changes. System dynamics is used for analysis of the behavior of complex real systems on a macro level, in management, politics, economics, environmental change etc. Important advantage of system dynamics is its efficiency due to its high degree of abstraction.

If virtual time is divided into a series of *discrete* periods, then event based simulation is used (Seila et al., 2003). Discrete event simulation advances 'time' to the moment (denoted by time stamp) in which at least one model entity needs to execute certain action or change its state. Simulation clock defines the beginning and the ending moments of time required for simulation execution. Discrete-event simulation models are primarily used for functional verification and performance evaluation of real world systems.

Standard methods for *concurrent* processes modeling are queuing networks, Petri nets and cellular automata.

- Queuing networks and Petri nets do not include mechanism for representing inhomogeneous space where the number of entities, their interactions and behavior change over time in dependence on their surroundings. If a conflicting situation occurs in the environment, then probabilistic factors or predefined fixed amounts of system resources and length of activities are used.
- Cellular automata are purely space based representations where each cell value is calculated on the basis of values of neighboring cells. However, modeling of individual behavior of an entity or modeling of deduction rules using cellular automata requires complex models and overwhelming computing resources (Klügl et al., 2004).

Some of the shortcomings of system dynamics and discrete event simulation as well as other methods for modeling concurrent processes can be overcome by multi agent simulation paradigm. The essential idea of agent based modeling and simulation (ABMS) is that complex phenomena (such as economic systems and business organizations) can best be represented as systems of relatively simple autonomous agents that