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THE PRACTICAL METHODS OF INTEGRATION OF SYSTEM DYNAMICS AND AGENT-BASED MODELING

The article deals with the identification of practical methods of integration of System Dynamics and Agent-Based Modeling as a platform for creation an Agent-Dynamic model, and also analysis of the combined models from different areas is made and the methods of combining approaches are explored.

Keywords: simulation, system dynamics, agent-based modeling, agent-dynamic modeling.

In a rapidly evolving business environment the question of searching of new tools for studying and analyzing economic entities becomes more important. One of the ways of information support for decision-making is a creation of the models using simulation tools.

Simulation modeling allows studying the problems of complex systems, for which analytical solutions are not available. It includes four approaches: System Dynamics, Dynamic Systems, Discrete Event and Agent-Based Modeling. This paper discusses the integration of the two of them – System Dynamics and Agent-Based Modeling.

Recent years a considerable interest in the study of the synergy between System Dynamics and Agent-Based Modeling was shown and it was noted that they can be combined in order to find solutions for complex problems [1].

By combining these approaches a number of factors that lead to improved quality of output information and, thus, to improved quality of decision-making can be taken into account.

The purpose of this work is to identify the practical methods of combining of System Dynamics and Agent-Based Modeling as a platform for creation an Agent-Dynamic model for IT-project management. To achieve this goal it is necessary to analyze the combined models from different areas and to explore the methods of combining approaches.

Popkov thinks that combining of System Dynamics and Agent-Based Modeling can take place in three cases [2].

When different objects of one system can not be modeled using the same approach.

When different objects of one system belong to different levels of abstraction.

When the use of the two approaches in one model facilitates the description and the creation of this model.

One of the earliest examples of the synergy between System Dynamics and Agent-Based Modeling is the model by Dong-Hwan and Jae-Ho, established in 1997 [1]. In their model they used array variables and, as a main method of combining, the modeling agents in System Dynamic environment. As a result of simulation, they showed that the new model, that was developed on the basis of System Dynamic and Agent-Based models, differs significantly from the original ones.

Through the cross-study of these two approaches Scholl gave an overview of the general modeling principles and identified areas in which the two approaches complement each other, and where they overlap [3].

One of the most detailed comparisons of System Dynamics and Agent-Based Modeling was done by Nadine Schieritz and Peter Milling [1]. A new method of integrating the two approaches was applied to the field of supply networks [4]. The model consists of two levels of aggregation. On the macro level a discrete Agent-Based Modeling is applied for modeling the interaction between companies-agents with each other. On the micro level the System Dynamics is used to model the internal structure of the company.

The integration of System Dynamics and Agent-Based Modeling was also used for modeling cellular receptor dynamics [5]. In this model the System Dynamics was applied in the part of systems simulation at a high level of aggregation and abstraction. The Agent-Based Modeling part was used for studying phenomena at the level of individual receptors and molecule.

Recently was made a cross-study of these approaches for tumour growth modeling [6]. Due to the developed model, which is based on the interaction between tumor cells and immune effector cells, it became possible to study specific problems of immune system.

Another example of integration could be found in automotive industry [7]. With the help of combination System Dynamics and Agent-Based Modeling in one simulation environment and the use of different aggregation levels, a detailed description of the socio-economic and dynamic complex system automotive market was made. As a result, product strategies with special regard to alternative fuel and powertrain technologies could be developed.

Jim Hines and Jody House created a theory of policy formation in organizations that explains the appearance of policies similar to biological evolution [8]. Their model consists of some projects (modeled as System Dynamics environment) each with a certain manager (modeled as agent). After the completion of the project every agent learns and adds new knowledge to its policy. The next project agent controls with updated policy.

Tobias Lorenz and Andrea Bassi combined two approaches for modeling the attractiveness of hotels for tourists [9]. For model creation they identified two methods. The first method considers modeling agents in the System Dynamic environment. The second one is modeling agents, that consist of System Dynamic structures, without predefined System Dynamic environment.

Borshchev also identifies two methods of combination [10]. According to the first method, a System-Dynamic submodels are created inside discrete interacting agents. A good example of it is the model of supply chains, in which processes are modeled by System Dynamics, and the interaction between the companies by Agent-Based Modeling tools. The second method implies modeling of agents that are situated

in the environment that is created by System Dynamics.

The following example of a combination is presented in the field of strategic management in agro-industrial cooperatives [11]. With the help of System Dynamics it became possible to predict the complexity of strategic management in regard of the need for conciliation and equilibrium of economic interests between the cooperative and its members. Through the Agent-Based Modeling the behavior of the cooperative's members was set up.

In the bank field is also an example of integration of approaches - it is a model of assessing the sustainability of a commercial bank [12]. This model includes the macroeconomic environment (System Dynamics part), which affects the subsystem of autonomous reactive agents - businesses, owners, etc.

A similar combining of approaches occurs in 3-agent model «state - the official - the owner,» which allows to study the behavior of agents under the conditions of conflict of interest, in order to simulate the shadow economy and corruption mechanisms [13]. In this model the method of modeling agents in System Dynamic environment was used.

An exploratory approach by Jim Duggan involves the use of System Dynamics models as a basis for Agent-Based Modeling [14]. His model includes the System Dynamics modeling of aggregated level, which consists of a large number of subsystems of agent level.

A good example of combination modeling approaches could be found in the field of corporate networks dynamics. Akkermans created a model of 100 agents in a System Dynamics simulation environment [15]. In his model, each agent has models of the performance of the agents, with whom he interacts and each agent differs in the degree in which he assesses long-term relationships over short-term performance.

On the basis of analyzed combinations, it can be concluded that for integration of System Dynamics and Agent-Based Modeling into one Agent-Dynamic approach one of the following methods can be used.

Modeling of interaction of agents at the macro level (the part of Agent-Based Modeling) and their internal structure at the micro level (System Dynamics part).

Modeling of one system at the macro level (System Dynamics part) and a certain number of interacting agents at the micro level (the part of Agent-Based Modeling).

Modeling of a certain number of objects on the macro level (System Dynamics part) inside which agents are modeled at the micro level (the part of Agent-Based Modeling).

Thereby, for selection of the most appropriate method of combining System Dynamics and Agent-Based Modeling for creation an Agent-Dynamic model of IT-project management it is necessary to define the structure and nature of the relationship of objects that will be included in the model.

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