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The concept of an intelligent system for modeling economic development of the region

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Abstract. The study is devoted to the concept of an intelligent system for modeling the economic development of a region, and especially to the interaction of individual economic agents with each other. The article presents the structure of an intelligent modeling system and the architecture of multi-agent models of economic agents. The result of the research is planned to be methods and algorithms for an intelligent decision support system for managing regional innovative development. The overall goal of the project is to create a complex system that facilitates the strategies development and the activities implementation aimed at enhancing and effectively managing of innovation in the regional context.

Keywords: intelligent system, multiagent models, decision making system, regional development, innovation, big data

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INTRODUCTION

In the context of technological progress and global competition, the integration of innovations into the regional socio-economic system is a key factor in science-based management. In this context, intelligent decision support systems are becoming an important tool for providing solutions to a set of problems in developing regional innovation strategies, and evaluating innovative projects where there is a high degree of uncertainty and information asymmetry [1]. But, as noted in a number of studies, the development of intelligent management systems at the municipal and state levels is associated with a number of dangers, including possible inconsistencies of decisions made by the system with the rules of law [2], an increase in the unemployment rate [3], as well as a decrease in tax deductions [4]. In addition, digitalization can lead to inequality of opportunities for citizens, associated not only with a lack of user competencies, but also with the operation specifics of the intelligent decision-making systems. For example, an analysis of the effectiveness of the digital benefit system in Norway showed a noticeable shift in coverage, directly correlating with the level of family income [5], which indicates the inaccessibility of government systems to certain categories of citizens. At the same time, the introduction of such technologies will significantly relieve the regional management system and simplify the decision-making process.

One of the tasks of developing intelligent public administration systems is to ensure the prediction of several indicators of an economic agent (organization, region, certain area) through accurate enough models. The question of selecting the most relevant model depends not only on the specific task, but also on the requirements for the model applicability in practice (for example, the criterion may be the computational complexity of the selected model). The approaches used can be divided into three groups: using mathematical modeling, statistics and machine learning methods. In the first case, it is assumed that there are proven models for economic agents that describe the movement of resources. Taken into account the complexity of an applicable model development, it is often necessary to use statistical approaches to predict the behavior of an economic agent. There are various approaches to model economic, social and demographic factors, based on which the economic development forecast of the region is built and optimal management decisions are made. For example, a demographic indicators assessment of municipalities and urban districts of the Republic of Bashkortostan made it possible to predict the spatial dynamics of labor resources [6]. This work allowed the authors to identify the direction of the working-age population outflow. Such a model, first of all, can make it possible to predict the dynamics of economic activity in different regions, and when using a regulatory system, ensure the necessary dynamics of human resources between different municipalities. A similar study, but in the context of spatial distribution and evolution of a comprehensive indicator of economic sustainability, was carried out for economic zones in China [7]. Based on the results of the analysis, the authors note a high level of economic sustainability in the eastern and coastal regions, and a lower level in the inland and northwestern regions of China. At the same time, within each region there is also unevenness associated with the significant difference of the central city's development in each province. Modeling of regional economic development for the western part of China [8] showed the influence of the following factors on the spatial distribution of gross domestic product: total capital formation, investment in fixed assets, government financial expenditures, human capital and the number of patents issued. Modeling a number of socio-economic scenarios for regional spatial development (based on the examples of the Primorsky and Khabarovsk Territories of the Russian Federation) using cellular automata in conjunction with geographic information systems made it possible to determine the dynamics of changes in a number of regional indicators, such as the construction of a road network, the construction of electric power facilities, the development of electrical grid infrastructure, the creation of large enterprises and the general level of economic attractiveness of the region [9]. The authors noted the effectiveness of using models based on the joint use of cellular automata with data obtained from geographic information systems. At the same time, it is worth noting the fairly widespread use of open geoinformation portals, such as OpenStreetMap, for the tasks of studying the spatial distribution of economic indicators (for example, the level of development and transport connectivity in the region) [10].

Among the technologies researchers consider the use of artificial neural networks, multi-agent modeling and blockchain technology [11]. The work [12] discusses data processing algorithms (detecting deviations from the normal value and using the KNN algorithm) when assessing risks and making decisions related to managing the regional economy. It is worth noting that intelligent systems (most often based on the use of artificial neural networks) are actively used to manage certain areas of economic activity (from regulating traffic flows [13] to managing the waste disposal process [14]).

CONCEPT OF AN INTELLIGENT SYSTEM FOR MODELING ECONOMIC PROCESSES

While developing an intelligent system for modeling the economic development of a region, it is necessary to ensure the most accurate modeling of indicators related to the movement of labor resources, production and sale of goods and services, as well as taking into account the influence of the regional management system on these indicators. To create such a model, a multi-agent approach can be used, which involves modeling the behavior of individual agent. Despite the significant computational load, such models make it possible to predict complex processes described through the interaction of many heterogeneous agents in the system. In particular, to model the behavior of regional economy, it is proposed to develop a model consisting of a set of individual economic agents responsible for the behavior of all actors (production, retail, labor resources, etc.). At the same time, each agent is determined by a set of available resources, as well as a knowledge base that describes the reaction to external conditions (changes in the labor market, tax system, etc.). In addition, if the agent is a producer of any resources, then the agent model requires a description of the required resources and production capabilities. In this case, the agent's behavior is determined by some target function depending on a specific group. The objective function can be maximization of benefits, the volume of accumulated resources, the level of quality of life and other parameters of an individual agent and the regional economy as a whole. The structure of the proposed regional economic modeling system is shown in Figure 1.

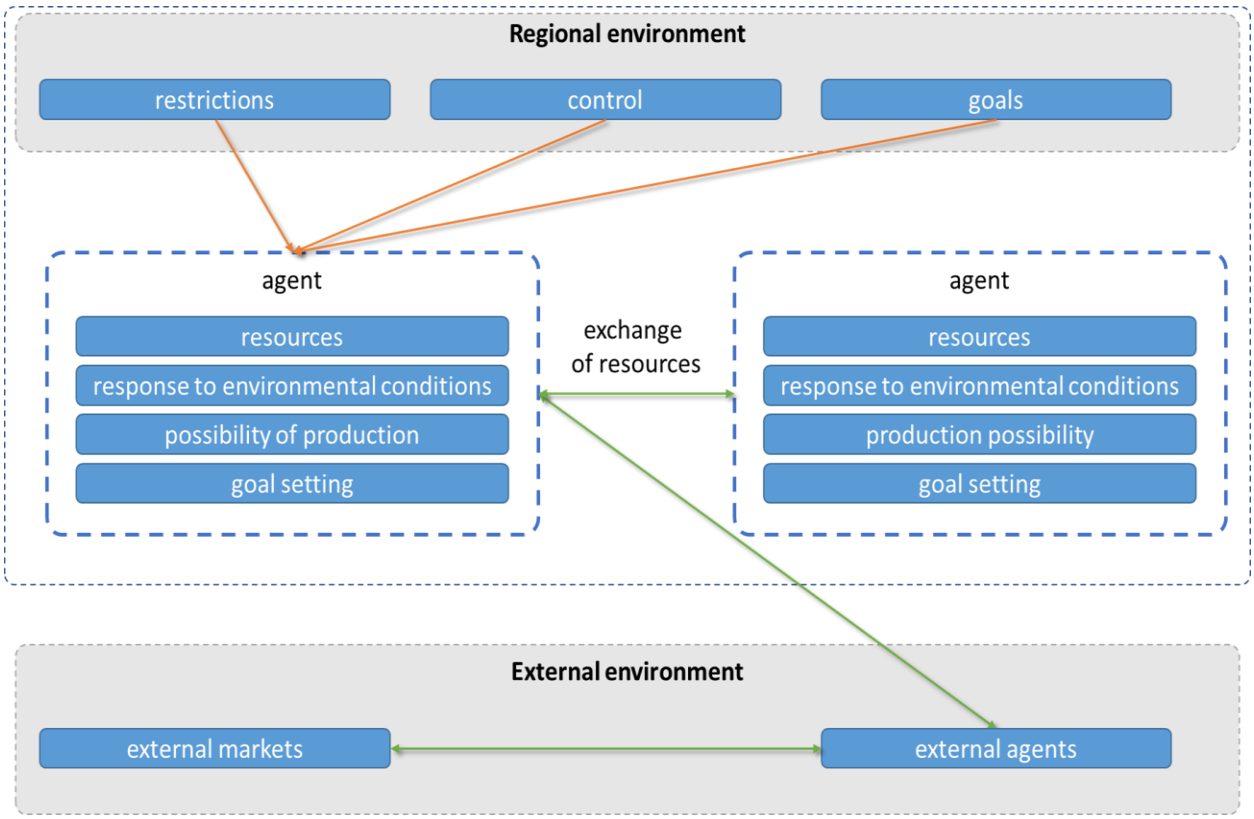

Fig. 1. *Structure of a multiagent model of a regional economy*

As can be seen from the figure, agents use the opportunity to exchange resources between themselves and the external environment, represented by external markets and agents as the

main tool of interaction. At the same time, agents are influenced not only by other agents, but also by the regional environment, which is responsible for limiting the actions of agents and some managerial influences. Moreover, the possibility of adjusting the goals of agents is considered (if the agent is a directly subordinate structure, e.g., a government agency).

Data collection is necessary to ensure the operation of such a system. In particular, it is required to implement automatic analysis of open registers and databases, as well as a statistics collection system. Such a system will provide some insight into the regional economy and the behavior of agents in it, which is necessary to fill the knowledge bases of agents in the model. It is necessary to take into account the practical impossibility of collecting complete and accurate statistics. The obtained information is sent to the database for further statistical analysis. These data are input parameters for a multi-agent model of economic processes occurring in the region. The simulation results are transmitted to the user. It is worth noting that the system interface should allow changing modeling conditions and be able to work with several users simultaneously. Figure 2 shows the structure of such a modeling system.

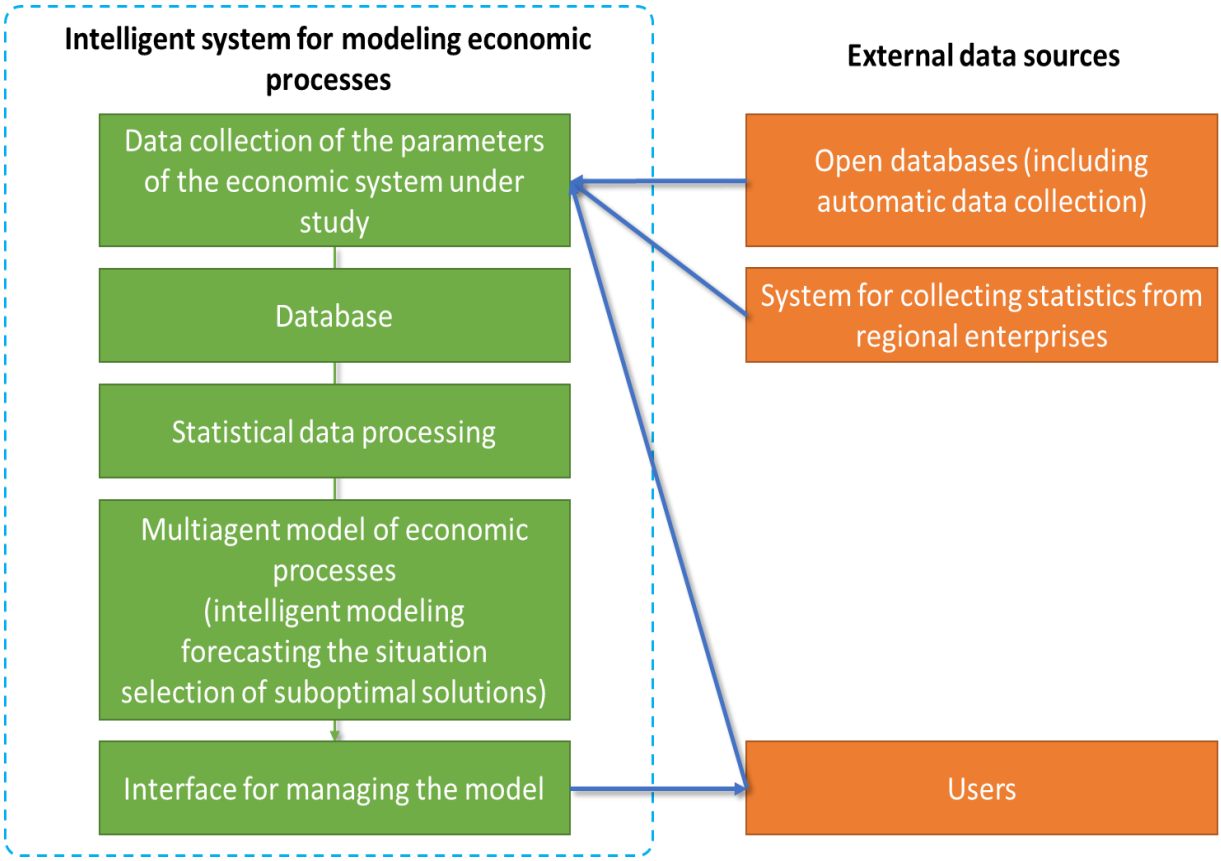

Fig. 2. *Structure of an intelligent system for modeling economic processes*

Multi-agent neurocognitive architectures [15], based on the modeling of proactive neurons, are considered as a formalism for an intelligent modeling system. In contrast to classical neural networks the used neuron model assumes the presence of its own knowledge base and target function, as well as separation by type. Interaction among neurons is carried out via dynamically concluded and terminated contracts responsible for the exchange of information and energy. The structure of such a multi-agent model is shown in Figure 3.

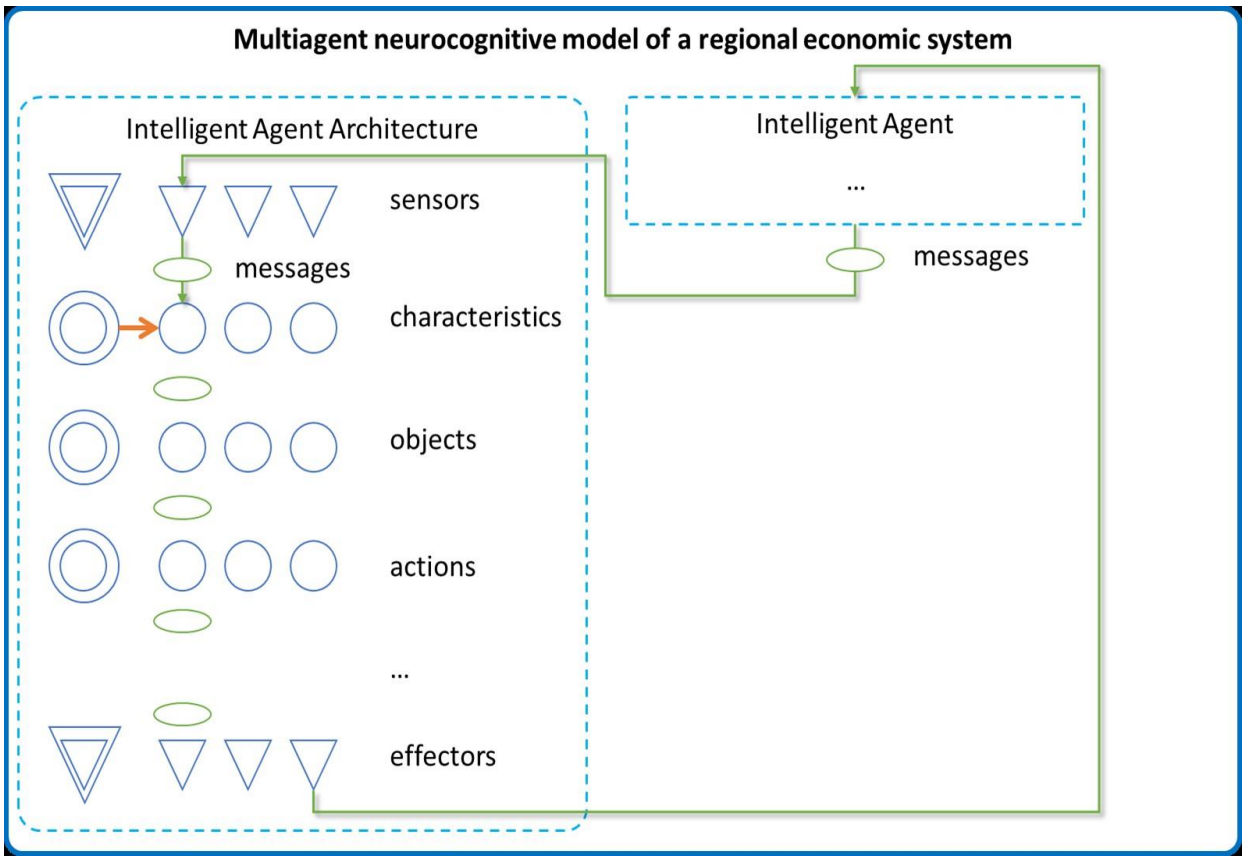

Fig. 3. *Basic architecture of the multiagent neurocognitive model*

The model includes many individual intelligent agents, each of which consists of several functional groups of neurons (layers), where there is a special neuron that is capable of creating new neurons in the architecture. The exchange of messages among the layers of the architecture, as well as among the sensors and effectors of different agents, allows the system to build an action plan that maximizes the target function of the entire intelligent agent as a whole. The use of such a formalism in the future will make it possible to simulate more complex processes of individual agents behavior, which will ensure the predictive accuracy of the developed model.

Conclusions

In the course of the study the concept of an intelligent system for modeling economic processes was developed, which can become part of the system for managing the innovative development of the region. The structure of a multi-agent model of a regional economy is presented, which considers individual economic agents, as well as the external environment and regional management system. The agent behavior in such a model is determined by the set of available resources, production capabilities, the knowledge base responsible for responding to external conditions, and the agent's target function. The formalism of the agent modeling system is to use multi-agent neurocognitive architectures. The proposed architecture will provide modeling of complex processes of interaction among economic agents, up to the movement of resources depending on external conditions and decisions made by the regional management system.

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