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AGENT-BASED MODELING IN URBAN STUDIES

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Abstract

Smart development of the urban environment requires non-speculative solutions. Today, the implementation of the "smart city" concept is at the stage of the digitalization of urban processes. Smart systems successfully cope with the generation of big data to help city services make decisions. The next stage in implementing the concept will be associated with an increase in the automation of smart systems. Thus, the problem of developing relevant approaches to the development of algorithms that will form their basis is being actualized. This approach can be simulation modeling and agent-based modeling in particular. This work aims to study the existing experience and outline the prospects for the use of agent-based in solving the problems of modern urban studies. A feature of the agent-based modeling methodology consists of representing complex objects from bottom to top as a set of autonomous subjects (agents). The latter can be individuals, legal entities, public law formations, and other abstract socio-economic relations subjects. Each agent has an individual objective function, which he seeks to maximize (minimize) through interactions with the environment and / or other agents. From the totality of actions and interactions of agents, the system's global dynamics is born, which is of particular interest for research.

Keywords: Agent modelling, digital economy, smart city

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1. Introduction

The increase in the speed of data transmission and the hardware power of telecommunication devices gave rise to the world of the Internet of Things - the sphere of direct interaction of objects connected to a common network. Smartphones today, as personal identifiers of a person in the digital world, can participate in the generation of big data used by smart analyzer systems: broadcast information about the location of carriers, report on their purchases. The collected data can be used, for example, to monitor traffic congestion, identify locations of high commercial activity, etc. Integrated systems can transmit to devices warnings about obstacles arising in the path of media, etc.

Pervasive digitalization launches integration processes in various areas of public life. Its result, in particular, was the emergence of the concept of a "smart city", which combines information and communication technologies with the Internet of Things (Mohanty et al., 2016), through which elements of the urban environment are able to interact with each other and with the population (Eremiaab et al., 2017; Marrone & Hammerle, 2018). Thus, a smart transport system, managing a network of traffic lights and dynamic road signs, is able to optimize the flow of vehicles. Smart healthcare optimizes the distribution of patient flows between polyclinics.

2. Problem Statement

The problem of intensifying innovative development is the key strategic agenda of modern Russia. One of the most important areas of its implementation is the digitalization of the country's socio-economic space, which, in particular, consists in updating the concept of a smart city based on the integration of information and communication technologies and the Internet of things (Dovgopol & Geras'kin, 2017; Makarenko & Loginovskaya, 2019; Shnyrenkov, 2019). The concept assumes the creation of an integrated digital system, 1) participating in the production of municipal services, 2) ensuring the rhythmic work of city services and 3) creating conditions for the participation of the population in city management.

3. Research Questions

Task to be solved during the study:

- analyze the experience of applying an agent-based approach to the study of elements of the urban environment;
- to define a research program for the application of agent-based modeling to the research and implementation of smart systems within the framework of the "smart city" concept.

4. Purpose of the Study

This work aims to generalize the existing experience of using agent-based modeling to study individual aspects of the functioning of urban systems and outline the prospects for using simulation modeling to optimize smart city systems.

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5. Research Methods

Simulation modeling and an agent-based approach, in particular, could become a tool for testing and optimizing complex smart control systems (Ramazanov, 2017). Simulation modeling allows you to carry out emulation experiments, determining the influence of certain design options and methods of calibrating the designed smart systems on their functional efficiency (Roscia et al., 2013). The usefulness of agent-based modeling here lies in its focus on reproducing complex systems from bottom to top - from the actions of many elementary actors to the global dynamics of the system. This property of the agent-based approach actualizes its application in the design of smart control systems for the urban environment, the dynamics and functioning of which is determined by the actions and interactions of many independent actors with opposite goals. A feature of the agent-based modeling methodology consists in the ways of representing complex objects from bottom to top as a set of autonomous subjects (agents). The latter can be individuals, legal entities, public law formations and other abstract subjects of socio-economic relations. Each agent has an individual objective function, which he seeks to maximize (minimize) through interactions with the environment and / or other agents. From the totality of actions and interactions of agents, the global dynamics of the system is born, which is of particular interest for research.

6. Findings

Makarov and Bakhtizin used an agent-based approach to develop urban problems within the framework of the smart city concept. The authors, in particular, have developed a model for the development of retail trade in Moscow. The results of simulation experiments indicate a shortage of small shops in some areas, caused by the extremely high cost of land lease. The functionality of their other model makes it possible to predict the dynamics and structure of the food basket of socially significant objects in Moscow (schools, hospitals, orphanages). The third author's model is designed to assess the impact of investments on the condition of the housing stock. The conceptual basis of the model was formed by the assumptions about the diversification of housing in terms of the degree of deterioration, dynamics of demand and the availability of free areas for construction. The latest author's model investigated rational landscaping as a means of protecting the urban environment from polluting emissions. The conceptual elements in the model are tree agents and outlier agents. The environment of their functioning is formed by passive polluting sources and separate areas of the model space that need protection from them. The model allows one to assess the protective potential of various configurations of green spaces (Makarov et al., 2019; Drozhzhinov et al., 2017).

Continuing the urban ecology theme, consider in more detail the model developed by Ghazi et al. (2016) for comparative analysis of air pollution abatement measures. The model integrates two neural network and one agent module. The first GPD (Gaussian Plum Dispersion) module, based on data on the localization of pollution sources, the intensity of their emissions and the local wind rose, simulates the process of air pollution. GPD calculates the composition, average concentration and variance of the pollution generated by each source, and then feeds the results to the ANN (Artificial Neural Network) neural network module. The combination of the GPD and ANN modules allows the uncertainty aspect of

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the weather to be introduced into the analysis. Thus, GPD and ANN modules form the environment of the model space.

The agents are organizations whose activities are accompanied by polluting emissions. In addition to organizations capable of regulating the level of emissions produced, uncontrolled sources of air pollution (for example, forest fires) are introduced into the model. Through a system of fines and rewards, the regulator is able to stimulate agents to reduce emissions. Each organization makes a decision on changing emissions volumes based on its previous experience and the experience of its neighbors. Ultimately, each subject receives a negative or positive gain, which depends on the number of agents who entered and did not cooperate with the regulator.

The exogenous variables of the model were calibrated on the basis of data from the city of Annaba, the largest settlement in northeastern Algeria. "Its bowl-shaped relief contributes to stagnant air and temperature inversions." Air pollutants are constantly monitored, particle concentration is measured hourly. The dataset also includes four climatic parameters: wind direction and speed, temperature and relative humidity. The ANN neural network module was trained on the 2003 dataset and tested on the 2004 dataset.

The conditions of simulation experiments were determined by the number of regulated and unregulated sources of pollution; the maximum volume of their emissions and the level of pollution permitted by the regulator. In order to demonstrate the positive contribution of restrictive measures on emissions in situations of pollution crises, two scenarios were investigated using the model. One of the scenarios assumed, in addition to controlled, 15 uncontrolled sources of air pollution. The second included only uncontrolled sources. Both scenarios were tested in turn in the presence and absence of a regulator.

The simulation results showed that the presence of a regulator significantly reduces the concentration of pollutants in the air, even with a large number of uncontrollable pollution sources. Another important result of the study was the conclusion that it is impossible in many cases to achieve a decrease in pollution indicators to the target level by administrative methods due to the existence of natural sources of pollution, which, in turn, is the basis for setting an applied problem of determining realistic benchmarks for pollution regulating organizations (Ghazi et al., 2016).

Agent-based modeling has a high potential in researching transport and pedestrian logistics problems. Thus, in the Helbing and Mulnar (1995) pedestrian traffic model, pedestrian agents differing in their speed of movement perform the trivial task of moving from point A to point B. The trajectory of agents' movement is determined by the presence of obstacles on the way: passive objects (pillars, blocks, signs, etc.) and other moving agents. The non-trivial result of the model implementation is the streaming structuring of the movement of agents. This fact attracts special attention due to the lack of global rules regulating the general movement of agents. The practical benefit of the Helbing and Mulnar, model lies in the possibilities of its use for organizing the comfortable and safe movement of people in pedestrian areas.

Using an evacuation model, Helbing and Vicsek (2000) tried to answer the question of how spatial organization affects the speed and safety of pedestrian traffic. The agents in their model collide with passive objects and with each other, get injured and slow down their movement. With the help of the

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model, in particular, it was possible to establish that two small separated exits are safer than one large one; physical obstacle before the exit, helping to reduce the accumulation of agents, accelerates the evacuation process. An increase in the speed of movement of agents contributes to the speed of evacuation only up to a certain limit, after reaching which individuals begin to create traffic jams in narrow places of space.

Nagel and Schreckenberg (1992) used an agent-based approach to investigate road traffic problems. In particular, scientists tried to determine the effect of traffic density on the number of cars passing the experimental section of the road per unit of time. In one model, the driver agents are programmed to keep their distance from each other. Going out onto an open section of the road, agents strive to achieve a certain desired level of speed. As the flow density increases, the agents slow down. To approach realism, the model introduced the possibility of agents committing errors when changing the speed of movement and observing the landing mode. Experimental results have shown that an increase in traffic density contributes to the efficiency of road traffic only up to a certain limit, after reaching which even minor errors of individual motorists begin to provoke massive traffic jams. The results obtained have a high potential for usefulness in the design of autonomous road traffic management systems.

The agent-based approach can be a useful tool for finding the optimal localization of urban infrastructure objects. As an example of using the simulation approach for these purposes, we can cite the Zulkarnay model, who investigated the problem of optimal localization of universities with a special status in order to maximize the positive externalities created by them (externalities), which consist in strengthening the connectivity of the academic space. Agents-universities moving within the framework of the model space (each area of which is characterized by factors such as the number and quality of the population, the development of industry and infrastructure, the presence of other universities nearby, etc.) in search of localization in which they could generate maximum utility. The result of the software emulation is the distribution map of systemically important universities.

Optimal localization tasks have high speculative potential. The advantage of the agent-based approach lies in the possibility of their objective machine solution based on predetermined criteria (Zulkarnay, 2019).

7. Conclusion

The agent-based approach can become a useful tool in solving problems of optimal localization of social and economic objects, elements of telecommunications and information infrastructure; algorithmization of smart control systems for transport and pedestrian logistics, courier, utilities and social services (Yeung, 2018). The benefit of simulation here lies in predicting the development of events when implementing design solutions (for example, determining the effects from the implementation of various algorithms for the road traffic management system) before their direct commissioning. Attempts to find the ideal setting for a smart system by trial and error can result in damage that significantly exceeds the stated utility of its operation for many years to come.

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