Agent-Based Modeling Using Artificial Intelligence as a Method for Creating Rational Consumption and Production Models

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Abstract. In a world saturated with rapid changes and uncertainty, the development of methods for forecasting and resource management is an important task for individual enterprises, groups of enterprises and holdings, as well as for entire territorial entities and the country itself. Agent-based modeling using artificial intelligence (AI) and machine learning technologies is becoming a powerful tool for creating sustainable consumption and production patterns.This article discusses how agent-based modeling as a method for describing a real system of consumption and production processes in symbiosis with artificial intelligence to determine the input parameters of the model provide new opportunities in the process of modeling complex resource management systems, which is further reflected in the rational consumption of resources.

1 Introduction

In the context of developing consumption and production models to assess their accuracy and viability, simulation modeling is often used. It is a methodological approach that takes a variety of input variables as input and predicts the key indicators of the model output. Among modern system modeling tools, agent-based modeling is considered to be the most accurate and objective. The agent-based model, or ABM, is a kind of society of digital agents that have their own different parameters, capable of imitating the behavior of various real-world systems from small economic and social objects to larger systems, for example, the operation of an enterprise or the population of an entire region. Thus, this model can reflect the dynamics of the socio-economic characteristics of the system as a result of the interaction of many independent agents, taking into account their diversity [8].

Due to the ability to change a large number of parameters, the ABM has a high degree of flexibility and adaptability. This makes it possible to conduct a variety of experiments, simulating possible scenarios for the development of the socio-economic system and assessing its response to various managerial influences.

However, ABM has a peculiarity: when creating and configuring the model, you need to use random variable values. As experiments progress, these values can be fine-tuned to specific situations. In this context, it is proposed to optimize the ABM training process using machine learning, neural networks, and artificial intelligence. This will make it

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possible to select input variables not randomly, but using trained neural networks or artificial intelligence [2].

AI technologies add another layer of functionality to agent-based modeling, as agents can learn from data and experience, which can make them more adaptive, as well as add another functional step with intelligent selection and configuration of predictors. Neural networks, machine learning algorithms, and other AI techniques allow agents to analyze large amounts of data and identify patterns that may not be visible to humans.

In economics, agent-based modeling is widely used to analyze and optimize consumption and production processes. In today's economy, there are many factors that influence decision-making by both consumers and producers. Agents in this model can be both individual consumers and firms [3].

2 Materials and Methods

Simulation modeling is a method that involves studying a real system and then conducting experiments on its accurate digital model. Further, the results of modeling are analyzed, and subsequently, based on the analysis, adjustments can be developed within the subject area of the system to improve certain indicators. At the same time, this type of models makes it possible to create a "digital twin" of the control object, which enables to interactively track changes at various parameter values and optimize them [12].

The use of agent-based models as a tool to support managerial decision-making enables you to test managerial decisions on an artificial society and predict socio-economic dynamics in a comprehensive manner, simultaneously at all levels of management: from an individual to a region, a district and a country, as well as to consider the process of consumption and production of production resources [14].

Depending on the direction of the model, basic models describing the basic needs and behaviors of agents within the designated subject area are integrated into the core. In the created artificial environment, they strive to recreate the environment as accurately as possible, with basic functionality, and imitate the behavior of agents associated with the consumption of resources [4].

One of the most promising digital tools for strategic planning that meet these requirements is represented by agent-based decision support systems (DSS). These systems are rapidly gaining popularity and are actively used abroad to improve strategic decision-making processes in various areas, including healthcare management, medical diagnostics, logistics, information technology, solving problems of task allocation, and others [5].

Agent-based DSS is a specialized type of decision support system based on complex agent-oriented models with an intuitive interface. Thus, agent-based DSS belongs to the category of model-driven decision support systems and consists of a core (agent-based model) and add-ons (interface) [7].

In the AnyLogic environment, there are different types of experiments that allow you to perform experiments in the model depending on the researcher's task, the following tools can be distinguished:

- A simple experiment. This type of experiment is a run of the model with parameters that are set by the researcher.
- Variation of parameters. This type of experiment is the operation of a model with different variants of parameters to find the parameters at which the best value of the objective function of the model is achieved.
- Optimization. This tool runs the model with different parameter values. This experiment allows you to compare the behavior of the model at different parameter values and then select the most appropriate parameter values.

– Comparison of "runs". This tool allows you to interactively enter various parameters in the model and then run the model.

– Sensitivity analysis. This tool performs several "runs" of the model, changing the values of one of the parameters. As a result it is shown how the results of the model execution depend on changes in the value of the parameter.

– Calibration. The calibration tool allows you to find the values of the model parameters at which the results of running the model most closely match the specified data [9].

3 Results and Discussions

Based on the importance of training agents to make decisions that depend on the input predictors of the AI model, it can be said that agents strive to achieve certain goals that allow them to create rational consumption and production patterns that optimize the use of resources and reduce waste. Such models can be applied to various spheres of human activity, since rational behavior in the use of resources is an important part of society as a whole. Therefore, it is possible to distinguish economic modeling, where agents can represent companies, consumers, banks and other market participants. Using agent-based modeling with AI, it is possible to analyze the impact of various factors, such as price changes, tax policy, and inflation on market conditions and predict the reactions of market participants. Also, in the field of logistics and transport, agents can represent cargo owners, transport companies and customs services. AI-powered agent-based modeling helps optimize routes, schedules, and cargo allocation, taking into account various constraints and changing conditions. It is important to note the possibilities of environmental modeling, where agents can represent species, ecosystems, and human activities. Agent-based modeling with AI can be used to study the impacts of climate change, resource use, and environmental protection strategies on biodiversity and ecosystems [10].

When implementing agent-based modeling, an integral part is the process of selecting and working out predictors, factors that reflect the direct impact on the behavior of the model, and the use of artificial intelligence for this process can significantly simplify, as well as improve the subsequent efficiency and accuracy of modeling. Let's take a look at some of the functionality:

1. Feature Selection: Intelligent algorithms, such as heuristic search – genetic algorithms, can be used to automatically select the most important traits from a large data set. This allows you to reduce the amount of data, reduce noise, i.e. improve the quality of the data and improve the process of generalizing the model.

2. Analyzing the importance of features, using feature mining techniques such as random forest or gradient boosting, helps to identify the factors that have the greatest impact on the target variable (model outputs), which will help focus attention on the most important and meaningful predictors.

3. Clustering and categorization of features. Artificial intelligence algorithms can be used to automatically cluster features, which can further simplify the model's work based on the possibility of a similar process for processing predictors within groups.

4. Correlation analysis that highlights the relationship between traits. Depending on the degree of correlation, the features can be combined or one of them can be excluded.

5. Regularization: In machine learning techniques such as linear regression, you can use regularization (such as L1 or L2 regularization) to automatically select the most important features and reduce the impact of insignificant ones.

6. Synthesis of new traits: AI algorithms facilitate the extraction of new features based on existing data, which can be useful for identifying implicit dependencies.

7. Recurrent neural networks. In the case of time series or sequential data, you can use recurrent neural networks (RNNs) to automatically extract temporal dependencies and identify important factors.

8. Deep Neural Network Training: Deep neural networks can be used to efficiently extract features from large and complex data, simplifying the predictor selection process.

9. Iterative approach: The process of selecting predictors can be iterative, with predictors gradually added or removed from the model based on its performance [11].

When considering the influence of artificial intelligence in agent-oriented modeling, one can notice the trends and biases presented in the table 1.

Table 1. Reflection of Artificial Intelligence in the Analysis of Factors Influencing the Agent-Based Model of Consumption and Production

The Factor of Influence of the Consumption and Production Model and the Features of Agent-Based Modeling	**Description of the Consumption and Production Pattern Factor**	**Reflection of the influence of the consumption and production model on resources (output values)**
Supply and Demand Forecasting	Agents equipped with artificial intelligence can analyze market trends and predict future changes in supply and demand, which helps companies manage inventory and prices more efficiently	Rational consumption of resources (including the organization's resources: raw materials for production, time and financial costs)
Consideration of individual features	Agent-based modeling allows you to take into account the diversity of agents and their individual characteristics, which is especially important in the field of consumption, where preferences and needs can vary significantly.	Qualitative study of needs in the allocation of consumption resources
Cost Planning Process	The use of artificial intelligence contributes to the development of the functional ability to make decisions on asset allocation, analyze risks and predict return on investment, as well as analyze vulnerabilities and cost points of production	There is an in-depth and qualitative analysis of aspects related to the production process in a resource-constrained environment
Adapting to changes in the external environment	Agents with artificial intelligence are able to quickly adapt to changing market conditions and make relevant decisions.	In the context of the digitalization of the economy and the active influence of information technologies on production processes in conjunction with the influence of external factors (political, natural, etc.) Rapid adaptation will allow for a better and more rational transition to new processes of resource consumption and production.

4 Conclusion

The use of artificial intelligence in agent-based modeling to create sustainable consumption and production patterns provides many benefits and significantly improves the quality and efficiency of modeling. It is of paramount importance that processes related to the analysis of big data can be automated, which makes it possible to take into account various factors and variables in models, especially in the context of rational management, where it is necessary to take into account many external factors, and to optimize further decisions of agents based on goals and constraints that directly affect the efficiency of production and consumption of resources It is worth noting that the use of artificial intelligence improves the model's ability to make forecasts and analyze the probability of the development of various scenarios, which further helps to manage risks and make more informed decisions based on data within the model. When creating agents with artificial intelligence, it becomes possible to adapt to new situations and changes in the market, which is especially important in a rapidly changing environment, based on the ability to learn from experience and changing conditions, which directly makes the agent model more real and closer to the actual situation.

It is also important to improve decision-making in agent-based models with artificial intelligence technologies, where recommendations and predictions can be extracted that help agents make more informed decisions. The emergence of an opportunity for the exploration of alternative strategies, experimenting with different strategies and scenarios to determine the best way to achieve the set goals, are also valuable.

Thus, the use of artificial intelligence in agent-based modeling opens up new opportunities for creating rational consumption and production models, as well as significantly improving the accuracy, speed and ability of models to adapt to changing conditions. This makes such models a very powerful tool for managing resources, optimizing business processes, and making strategic decisions in today's fast-paced world.

References

1. C. Deissenberg, S. van der Hoog, H. Dawid, EURACE: A massively parallel agent-based model of the European economy. Applied Mathematics and Computation, **204(2)**, 541-552 (2008)
2. F. Bertani, L. Ponta, M. Raberto, A. Teglio, S. Cincotti, The complexity of the intangible digital economy: an agent-based model. Journal of Business Research, **129**, 527-540 (2021)
3. B. A. Furtado, I. D. R. Eberhardt, A Simple Agent-Based Spatial Model of the Economy: Tools for Policy. Journal of Artificial Societies and Social Simulation, **19(4)** (2016)
4. L. Tesfatsion, Agent-based computational economics: modeling economies as complex adaptive systems. Information Sciences, **149(4)**, 262-268 (2003)
5. R. Koide, H. Yamamoto, K. Nansai, S. Murakami, Agent-based model for assessment of multiple circular economy strategies: Quantifying product-service diffusion, circularity, and sustainability, Resources, Conservation and Recycling, **199**, 107216 (2023)
6. E. A. Rossoshanskaya, T. A. Doroshenko, N. A. Samsonova, Agent-oriented demographic model of the Far East as a tool for supporting managerial decision-making. Public administration. Electronic Bulletin, **94**, 203-224 (2022)

7. S. V. Begicheva, Development of a simulation model for a comprehensive assessment of the quality of emergency medical care. The tenth All-Russian Scientific and practical conference on simulation modeling and its application in science and industry "Simulation modeling. Theory and Practice" (IMMOD-2021): Proceedings of the Conference, 105-112 (2021)
8. V. D. Voroshchenko, V. P. Egorova, M. A. Gorkavy, Intelligent module for optimization and efficiency management of the production process based on an agent simulation model. Scientific notes of Komsomolsk-on-Amur State Technical University, **1(65)**, 85-93 (2023)
9. V. L. Makarov, A. R. Bakhtizin, E. D. Sushko, The use of agent-oriented models to expand the strategic functionality of the situation center of Kuzbass. Industrial economics, **13(3)**, 300-307 (2020)
10. D. M. Nazarov, A. D. Nazarov, Prospects of artificial intelligence and their impact on the digital economy of Russia. Smart Digital Economy, **2(3)**, 55-59 (2022)
11. D. S. Benz, The Manager, **12(6)**, 49-66 (2021)