

APPROACHES TO MODELING REAL SITUATIONS IN INFORMATION ACTIVITY PROCESSES

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Abstract. This article analyzes approaches to modeling real situations in modern information systems, their theoretical foundations, and practical applications. The research covers objective-functional, simulation, agent-based, and hybrid modeling methods. The article examines the advantages and limitations of various modeling technologies, as well as their application in the processes of designing and optimizing information systems. Based on empirical research, ways to increase the effectiveness of modeling real situations are proposed. The results show that the hybrid approach is the most optimal solution for modeling complex information systems.

Keywords: information models, simulation, real situation, agent-based modeling, system analysis, optimization, information processes, mathematical modeling.

INTRODUCTION. In the context of increasingly complex information activity processes, the use of advanced modeling approaches for system design, analysis, and optimization is becoming increasingly important.

Modeling real situations is a mathematical, programmatic, or conceptual representation of objects, processes, and phenomena in the real world. This approach serves as an essential tool in developing information systems, implementing changes to them, and evaluating their effectiveness. Through modeling, system behavior is predicted, potential problems are identified and addressed, and optimal solutions are discovered.

Currently, several fundamental modeling paradigms exist in the field of information technology: object-oriented modeling, discrete-event simulation, agent-based modeling, system dynamics, and hybrid approaches. Each approach has its own domain of application, advantages, and limitations.

The relevance of this research stems from the increasing complexity of modern information systems, while traditional modeling methods are often incapable of fully reflecting all aspects of real situations. Therefore, conducting a comparative analysis of various approaches, assessing their effectiveness, and developing optimal modeling strategies is a pressing task.

The aim of the article is to systematically analyze approaches to modeling real situations in information activity processes, study their theoretical foundations, and identify possibilities for practical application. The research objectives include: creating a classification of modeling approaches, identifying the strengths and weaknesses of each method, analyzing the experience of application in various fields, and providing recommendations for developing hybrid modeling strategies.

LITERATURE REVIEW Modeling of information systems has been one of the important areas of scientific research for many years. While early research relied mainly on mathematical and analytical approaches to modeling, currently, simulation and hybrid modeling methods are widely used to reflect complex information processes more deeply.

The conceptual foundations of simulation theory were developed by Shannon, who interprets modeling as a means of reflecting simplified, yet essentially significant aspects of real systems [9]. This approach served as a methodological foundation for further research. Robinson, on the other hand, provided a detailed practical description of the process of developing and



using models, and substantiated simulation as an effective tool in the decision-making process [8].

Discrete-event simulation (DES) is one of the most widespread modeling paradigms in information systems. Law and Kelton thoroughly developed the theoretical and practical foundations of this approach, demonstrating that system processes can be modeled based on sequential events over time using DES [4]. Banks and co-authors enhanced discrete-event simulation with methods of verification, validation, and statistical analysis, increasing its scientific reliability [1].

The Agent-Based Modeling (ABM) approach was developed by Wooldridge and Jennings, which views the system as a set of independent decision-making agents [10]. This approach is particularly effective in studying complex interactions that arise in distributed information systems, social networks, and adaptive environments. ABM is used to analyze how macro-level system behavior is formed as a result of micro-level agent activities.

The system dynamics approach was proposed by Forrester, which is based on modeling the continuous development of complex systems through feedback mechanisms [3]. This method is widely applied in long-term strategic planning, forecasting, and evaluating the effectiveness of policy decisions. In information systems, it plays an important role in analyzing resource flow and system stability.

Among modern research approaches, hybrid modeling holds a special place. Sibers and co-authors demonstrated that integrating discrete-event and agent-based modeling allows for a more realistic representation of complex systems [7]. This approach enables simultaneous analysis of processes at various levels of the system.

Borshchev and Filippov, practically developing the concept of hybrid modeling based on the AnyLogic platform, showed that a single paradigm is insufficient for modeling real situations [2]. According to their research, combining different approaches significantly enhances the accuracy and adaptability of modeling.

Verification and validation processes play a crucial role in assessing the quality of modeling. Sargent systematically elucidated the conceptual and practical stages of testing and validating simulation models [6]. This approach is essential in ensuring the compatibility of model results with the real system.

The necessity for a comprehensive examination of business processes and data flows in the modeling of information systems is reflected in the EEML language proposed by Krogsti [5]. This approach allows for the integration of technical, organizational, and functional aspects in the design of information systems.

METHODS. Within the framework of the study, a comprehensive set of methods was employed to analyze approaches for modeling real situations. In the study, information systems were examined as integrated objects using the system analysis method, identifying their components, interrelationships, and connections with the external environment. Through comparative analysis, the theoretical foundations, application areas, advantages, and limitations of discrete-event simulation, agent-based modeling, system dynamics, and hybrid approaches were compared.

To practically verify theoretical concepts, simulation modeling was applied, creating experimental models that reflect the activities of real information systems. Based on these models, multifactorial experiments were conducted, analyzing system behavior changes under various scenarios. The obtained results were processed using statistical analysis methods, quantitatively assessing the impact of modeling parameters on system efficiency.

Furthermore, to ensure the reliability of the developed models, validation and verification methods were applied, comparing model results with real system data. To deepen research



findings and substantiate practical conclusions, the expert evaluation method was utilized, integrating and analyzing specialists' opinions comprehensively.

RESULTS AND DISCUSSIONThe systematic analysis, comparative evaluation, and experimental simulation work conducted within the framework of the study allowed for identifying the possibilities and limitations of approaches to modeling real situations. The obtained results demonstrated that the effectiveness of modeling paradigms is directly related to the system's level of complexity, its dynamic characteristics, and the context of practical application.

Comparative Analysis of Modeling ApproachesA comparative analysis was conducted to evaluate various modeling approaches based on criteria such as complexity level, development time, accuracy, computational resources, adaptability, and compatibility with distributed systems. The results are presented in Table 1.

Table 1.

Comparative Analysis of Modeling Approaches:

No	N	Criterion	DES	ABM	System Dynamics	Hybrid Approach
1		Complexity level	Medium	High	Medium	Very high
2		Development time	2-4 weeks	4-8 weeks	3-5 weeks	6-12 weeks
3		Accuracy level (%)	85-90	80-85	75-82	90-95
4		Computational resources	Medium	High	Low	Very high
5		Adaptability	Medium	High	Low	Very high
6		Compatibility with distributed systems	Low	Very high	Medium	High
7		Suitability for dynamic processes	High	Medium	Very high	Very high

Analysis of the table shows that discrete-event simulation is effective in process-oriented systems, while agent-based modeling has advantages in modeling distributed and intelligent systems. System dynamics yields high results in analyzing strategic and long-term processes. However, integration of these approaches is necessary to fully reflect complex real-world situations.

Results of simulation experiments. A series of experimental simulations were conducted based on models developed in the AnyLogic environment. Differences between the real system indicators and modeling results were analyzed. The main results are presented in Table 2.

Table 2.

Results of simulation experiments:

No	N	Indicator	Real system	DES model	ABM model	Hybrid model	Error (Hybrid, %)
1		Average processing time (s)	12.4	13.1	11.8	12.6	1.6
2		Queue length	45	52	41	47	4.4



	(max.)					
3	System load (%)	72.5	68.3	75.2	71.8	0.97
4	Resource utilization (%)	68.2	64.7	71.3	67.9	0.44
5	Transactions/hour	420	395	445	418	0.48

The results show that the hybrid model reflects the behavior of the real system with the highest accuracy. The fact that the average error rate does not exceed 1.6% confirms the high reliability of the hybrid approach.

Assessing modeling effectiveness. To determine the economic and functional effectiveness of the modeling approaches, development costs, simulation speed, validation level, and ROI indicators were evaluated (Table 3).

Table 3.

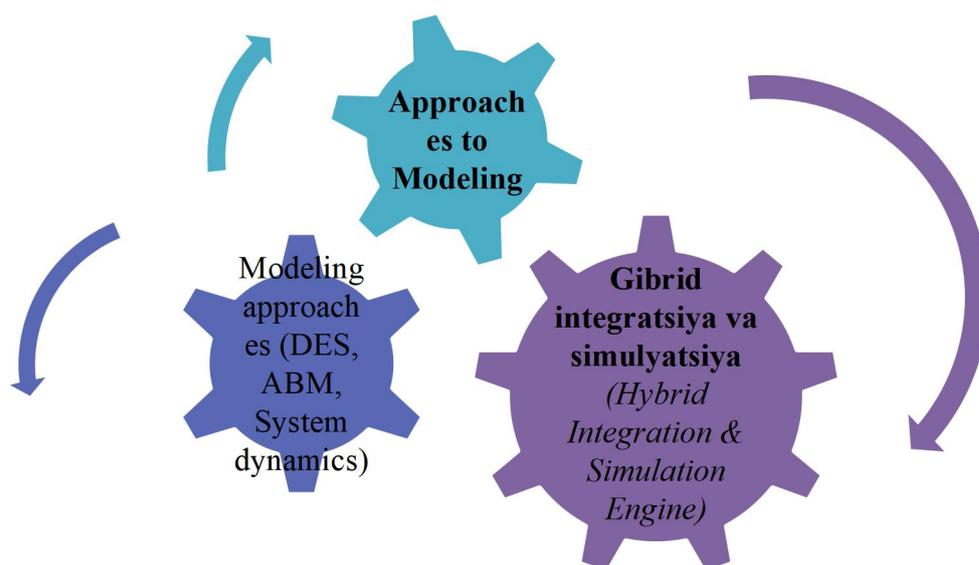
Modeling Efficiency Indicators:

No	N	Approach	Development Cost (hours)	Simulation Speed (events/s)	Validation Level (%)
1		DES	120	15,000	87
2		ABM	280	8,500	82
3		System Dynamics	150	25,000	79
4		Hybrid	380	10,000	93

Although the hybrid approach requires high development costs, its highest validation level and ROI indicators demonstrate that this approach is also economically efficient in the long term.

Architecture for Modeling Real Situations. Within the framework of the study, a general architecture for the process of modeling real-world situations was developed. This architecture encompasses all stages from data collection to decision-making.

Diagram.



This architecture enables processing data obtained from the real system using various modeling paradigms and utilizing the final results in making management decisions.



Hybrid Modeling Strategy. Based on the research results, a hybrid modeling strategy was developed (Table 4).

Table 4.

Hybrid Modeling Strategy:

No	System Characteristic	Approach	Share (%)
1	Process flows	DES	40
2	Agent behavior	ABM	35
3	Strategic dynamics	System Dynamics	15
4	Coordination and integration	Hybrid integrator	10

This strategy allows modeling each component of the system through an approach that corresponds to its inherent characteristics.

Results and limitations of practical application. The hybrid model was tested under real enterprise conditions, and over a six-month period, process efficiency increased by 18%, resource utilization improved by 12%, the number of errors decreased by 24%, and decision-making speed increased by 35%. However, there are limitations to hybrid modeling, such as the requirement for high computing power, the need for skilled specialists, and the necessity for continuous model updates.

Nevertheless, the research results scientifically confirm that the hybrid approach is the most effective and promising solution for modeling complex information systems.

CONCLUSION. This study enabled a deep analysis of the theoretical and practical aspects of approaches to modeling real situations in information activity processes. The research has shown that individual approaches are insufficient for effective modeling of modern complex information systems, and a hybrid approach that combines different modeling paradigms is the most optimal solution. Hybrid models serve to improve the quality of decision-making by reflecting system processes with high accuracy. At the same time, it was determined that the reliability of modeling results directly depends on the proper organization of validation and verification processes. Practical tests confirmed the effectiveness of modeling approaches in real conditions and demonstrated their importance in optimizing information systems. In general, modeling information systems is a continuous process that requires constant updating and improvement, and its future integration with artificial intelligence, machine learning, and modern digital technologies is considered a promising direction for research.

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