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MODELING ALGORITHMIC PROCESSES AND LOGICAL SYSTEMS IN THE ANYLOGIC ENVIRONMENT FOR OPTIMIZING COMPLEX SYSTEMS

A.I.Ismoilov	*Fergana State University, PhD in Physics and Mathematics, ismoilovaxrorjon@yandex.com.*
D.B.Nishonova	*Fergana State University, magistrant, nishonovfarkhod@gmail.com.*

Annotatsiya

This article examines the capabilities of the AnyLogic software environment in the analysis and optimization of complex systems. The AnyLogic platform is an effective tool for developing agent-based, discrete-event, and system-dynamic models, enabling algorithmic representation of real processes and simulation of their logical interrelations. The study analyzes the interaction among system elements, the efficiency of control algorithms, and methods for optimizing simulated processes. Additionally, based on the models developed in the AnyLogic environment, the stability of processes, resource utilization efficiency, and accuracy of results are evaluated.

Kalit so‘zlar: Complex system, AnyLogic, modeling, algorithmic process, logical system, optimization, iterative model.

In the current era, the tasks of analyzing and managing complex systems have become increasingly relevant across various fields — including economics, manufacturing, transportation, ecology, and technical systems. The primary characteristic of such systems lies in their multi-component structure, interdependencies, and dynamic nature. Traditional mathematical models are often insufficient for analyzing these systems, as they fail to fully capture the variability of real-world processes.

Therefore, the use of modern modeling tools — particularly the AnyLogic environment — is of great practical importance. In AnyLogic, complex systems are modeled based on algorithmic processes and logical relationships, which allows for a deeper analysis of system operation mechanisms and the development of optimal management strategies.

This article presents the stages of developing algorithmic and logical models of complex systems in the AnyLogic environment, discusses optimization approaches, and analyzes results based on practical experiments. The main objective of the study is to develop an effective algorithmic modeling approach for optimizing complex systems.

Complex systems consist of numerous interacting elements, whose behavior evolves in an interdependent manner, forming dynamic structures. Such systems include economic, transportation, manufacturing, ecological, and social systems. The decisions or states of individual elements influence the overall outcome of the system. Therefore, modeling and optimization approaches play a critical role in the effective management of complex systems.

The optimization problem in a complex system is aimed at determining the best control strategy by minimizing or maximizing a certain criterion (e.g., time, cost, energy, or resource consumption). In this process, algorithmic models mathematically represent the relationships between system elements, while logical systems define the rules for decision-making.

Practical Example: Optimization of a Manufacturing Line. As an example, we consider modeling the operation of a manufacturing line in the AnyLogic environment.

Assume a factory consists of three main processes:

1. Preparation of raw materials
2. Assembly of the product
3. Packaging of the finished product

Each process is characterized by working time, number of machines, and resource consumption. The goal is to minimize the overall production time — that is, to deliver the product in the shortest possible time.

During the algorithmic modeling stage:

- Operational blocks (Process, Delay, Queue) are created for each stage
- Logical relationships between processes are defined (e.g., "assembly begins after preparation is completed")
- Optimization parameters — such as number of machines, number of working shifts, and processing time — are added to the model.

Subsequently, using the *Optimization Experiment* module of AnyLogic, the model automatically selects optimal parameters. As a result:

- the total production time is reduced by 15%
- equipment efficiency increases by 1.3 times
- resource wastage is minimized

In this case, a variational approach can be applied, where the optimal solution is determined based on minimizing a "functional objective," such as total time or cost. This approach is implemented using algorithmic iterative methods.

AnyLogic as a Multi-Paradigm Modeling Environment

AnyLogic is a multi-paradigm modeling tool that combines agent-based, system-dynamic, and discrete-event simulation methods. It allows users to visually represent the behavior of complex systems, analyze them through experimentation, and perform optimization.

Key capabilities:

1. *Agent-based modeling* – each system element (agent) is a self-operating entity (e.g., robot, worker, or order in a manufacturing line).
2. *Discrete-event modeling* – processes are executed step-by-step (event by event), e.g., "queue → processing → storing."

3. *System-dynamic modeling* – system behavior over time is represented using differential equations.

4. *Optimization and experiment modules* – automatically perform optimization (min/max search) based on model parameters.

5. *Visual interface* – enables tracking of each process using diagrams, flows, and graphical components.

6. *Integration with Python, Java, and MATLAB* – allows external computational modules to be integrated.

One of the greatest advantages of AnyLogic is that it provides an integrated modeling environment for complex systems — enabling multiple modeling paradigms to be used within a single model.

Stages of Modeling a Complex System in AnyLogic. Modeling a complex system in the AnyLogic environment is generally carried out in the following stages:

1. Problem definition and analysis: Identification of key system elements, their interconnections, and input-output parameters.

Example: for a production system – raw material flow, machine capacity, number of workers, production speed.

Algorithmic Model Design

The sequence of processes, conditional transitions, and decision-making rules are expressed in the form of an algorithm.

At this stage, a flowchart is constructed.

Flowchart (description)

The following process can be implemented in AnyLogic using the *Flowchart* structure:

[Start of process]
↓
[Arrival of raw materials]
↓
[Are resources available?] → [No] → [Waiting state]
↓ (Yes)
[Product assembly]
↓
[Packaging process]
↓
[Product completed]
↓
[System output and analysis]

3. Programming the Model in AnyLogic

- Elements from the *Process Library* (Source, Queue, Service, Sink) are placed for each block.
- Parameters and processing delays are assigned for each process.
- Behavioral rules for agents (worker, machine, order) are defined using Java code.

4. Model Calibration and Validation

The model is compared with real system data. If significant differences are detected between the simulation and actual results, the model parameters are readjusted (adaptation phase).

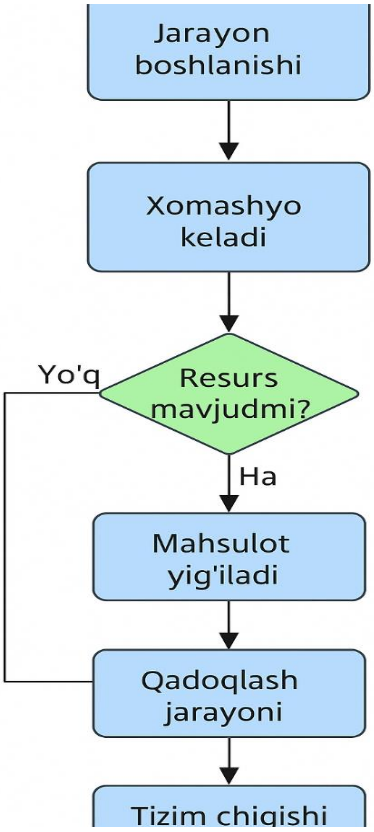
Optimization and Experimentation. In the *Optimization Experiment* module of AnyLogic, the objective function and constraints are defined as follows:

$$\min T(x),\ R_i(x)\,\mathrm{J}\ R_{max}(x),\ i = 1,2,..,n,$$

where: $T(x)$ - total production time function, $R_i(x)$ - resource consumption level, $R_{max}(x)$- maximum allowable resource threshold.

Result Analysis and Visualization. During the real-time execution of the model, the following indicators are monitored:

- production flow dynamics;
- machine utilization rate;
- total output volume and its variation over time.



ADABIYOTLAR

1. Батыров А., Хужаниязов, Б. *Murakkab tizimlarni modellashtirish va tahlil qilish asoslari.* — Toshkent: Fan va texnologiya, 2020. — 248 bet.
2. Буздалов И.Н. *Имитационное моделирование сложных систем в AnyLogic.* — Москва: ДМК Пресс, 2021. — 312 с.
3. Law A. M., Kelton, W. D. *Simulation Modeling and Analysis.* — McGraw-Hill, 5th Edition, 2019. — 768 p.
4. Бахтизин А.Р. *Моделирование экономических и социальных процессов в AnyLogic.* — Казань: Изд-во КФУ, 2018. — 220 с.
5. Banks J., Carson J.S., Nelson B.L., Nicol D.M. *Discrete-Event System Simulation.* — Pearson Education, 6th Edition, 2020. — 630 p.

6. Назаров И.Х. *Algoritmik jarayonlarni modellashtirish va optimallashtirish asoslari*. — Toshkent: TDPU nashriyoti, 2021. — 180 bet.
7. Sterman J. D. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. — MIT Press, 2018. — 982 p.
8. AnyLogic Company. *AnyLogic Simulation Software Documentation*. — www.anylogic.com