AUTOMATION OF ADAPTIVE CONTROL OF COMPLEX OBJECTS STATES TRAJECTORIES IN ARTIFICIAL INTELLIGENCE SYSTEMS

Denis I. Mutin (1), Alexey F. Kaperko (2), Sergey A. Sorokin (3), Dmitriy V. Sotnikov (4), Igor V. Atlasov (5), Nikita A. Ryndin (4)*

(1) Moscow State University of Technology “STANKIN”, Moscow; (2) National Research University Higher School of Economics, Moscow; (3) Research Institute of Computing Complexes named after M.A. Kartsev, Moscow; (4) Voronezh State Technical University, Voronezh; (5) Moscow University of Ministry of Internal Affairs of Russian Federation named by V. Ja. Kikot, Moscow
Russian Federation

* Corresponding Author, e-mail: csit@bk.ru

Abstract: Today, the problem of automating the control of the individual trajectory of the states of complex objects is relevant. It is necessary to influence the individual trajectory of the object's states, guided by certain parameters. The reaction should be adequate to change these parameters. The aim of the work is reasonable automation of adaptive control of complex objects and trajectories in artificial intelligence systems. Tasks to be solved: (1) Identification and evaluation of criteria by which it is possible to determine the level of the object's condition with a high degree of probability. (2) Creation of such a mechanism for issuing control actions to an object, on the basis of which it will be possible to create fully automated control trajectories that require a minimum of operator participation in the operation of the finished system..

Key words: adaptation, control, artificial intelligence system, linear convolution of parameters, state identification.

1. INTRODUCTION

Today, the problem of automating the control of an individual trajectory of states of complex objects is relevant. The individual trajectory of states is a directed graph on which the entire process of changing states is displayed. It largely depends on whether the object will be able to successfully use the state parameters or whether the resources for managing its trajectory will be wasted.

The system of states should be feedback, which should be expressed in influencing the individual trajectory of the object's states, guided by some of its parameters. The reaction should be adequate to change these parameters.

This leads to two problems of automating the control of state trajectories:

1. Selection and evaluation of criteria. What is obvious to a person is often very difficult to understand technically. In this regard, it is necessary to search and identify those criteria by which it is possible to determine the level of the object's condition with a high degree of probability.

2. The problem is in the layout of control tactics and the adequate issuance of control actions to the object. I.e., there is a need to create such a mechanism on the basis of which it is possible to create fully automated control trajectories that require a minimum of operator participation in the functioning of the finished system.

2. PREVIOUS RESEARCH

Many researchers have dealt with various issues related to the management of the individual trajectory of the state of a complex object. In [1], a task-oriented trajectory planning algorithm is considered, which allows you to reach a moving target on the surface and control it as quickly as possible, without specifying the moment of achievement. In [2], the problem of controlling a partially limited trajectory of an arbitrary reference frame rigidly bound to an object is investigated. In [3], a mathematical formulation of the problem of predicting the trajectory of motion is given. The solution is based on the training of an adaptive neurosemantic controller. In [4], in fact, the inverse problem is solved - an approach to tracking several objects is proposed, combining contextual features and trajectory prediction. Unfortunately, none of the works provides a solution for the preliminary classification of control objects and the creation of point (adaptive) control by varying the parameters of control actions using an artificial intelligence system.

The task of selecting and evaluating the criteria specified in the introduction is actually difficult only at the level of its formulation – here, expert assessments are also needed to help artificial intelligence. The aim of the work is reasonable automation of adaptive control of complex objects and trajectories in artificial intelligence systems.

3. CONTROL OF THE PROCESSES OF INDIVIDUALIZATION OF STATES USING ARTIFICIAL INTELLIGENCE

The individualization of the process of changing states, regardless of the means and methods of assessing states, should not significantly depend on the characteristics of the operator and the object. The adjustments create an individual trajectory of states [5], which includes an individualized control content adapted to the characteristics of the object, and created using an artificial intelligence system (AIS).

Let's consider a dynamic multiparameter system describing the current object's state: $\Theta(t) = (M(t)), C(t), P(t))$, where is the current time; $M(t)$ is the current level of the object's needs (integer); $C(t)$ is the current level of the object's capabilities (integer); $P(t)$ is the type of the object at the time of determining the state (integer).

We introduce the concept of the "target level of the object" Ω (real value), depending on the phase point of the multiparametric system $\Theta(t)$ and the evaluation system. The target level Ω can be obtained expertly. Multiple objects with different combinations of M, C, and P parameters can correspond to the same target level of an object. One of the options for calculating the current target level of the object Ω, suitable for subsequent use in an automated system for constructing an individual trajectory of states, is to set it as a linear convolution of parameters using normalized weighting coefficients in the form of an integral additive objective function [6]:

$$\Omega=\alpha\cdot M + \beta\cdot C + \gamma\cdot P;\ \alpha + \beta + \gamma = 1;\ 0 \leq \alpha,\ \beta,\ \gamma \leq 1.$$

The coefficient α characterizes the significance of the level of necessity in determining the target level of the object. The coefficient β determines the effect of assessing the level of capabilities of an object on the current target level. Finally, the coefficient γ gives the "contribution" of the features to the target level of the object [7]:

- the predominance of α makes it possible to characterize the process of changing states as focused more on the formation of high-priority parameters of the object;
- the predominance of β orients the control process towards capacity development;
- the predominance of γ determines the orientation of the state change process towards the search for a stable state of the object.

Let's consider the actual process of adapting the individual trajectory of states in connection with the current level of the Ω_{now} object and the current target level of the object Ω. The current level of the Ω_{now} object is, in fact, the current assessment, formed using various criteria scales. For various reasons, this estimate may differ from the current target level of the object. As a rule, $\Omega_{now}<\Omega$.

In an ideal situation, the process of changing states should bring the level of the object to Ω, but the question of choosing forms, means and methods for this achievement is debatable. All this is possible only if a number of conditions are met.

1. The current target level of the object Ω must be obtained before starting the state change process (Ω_0).This procedure includes a motivational survey of the object, its input testing, and diagnostics. In accordance with the value of Ω_0, the operator, using automation tools, forms a "starter" package for managing the object.
2. The value of the of the Ω_{now} should be evaluated as often as possible.
3. It is necessary to ensure maximum objectification of the estimate of the value of Ω_{now}, its independence from the level of contradictions between the operator and the object.
4. AIS should be ready for directional changes in the coefficients α, β, γ depending on possible changes in the state of the object.

4. COMPONENTS OF THE TRAJECTORY CONTROL SOFTWARE SYSTEM

The state trajectory management system is an add-on to the state management system and implies that the latter should have mechanisms for interacting with external software [8] (Figure 1). It reflects the modular structure of the state trajectory management system, internal interactions, as well as the relationship with the Object Assessment and Management System (FAMS). The information needed to make decisions is stored in a database. In general, the operation of the system can be reduced to processing data from it. Let's take a closer look at the functions of the parts that make up the system and their role in information processing:

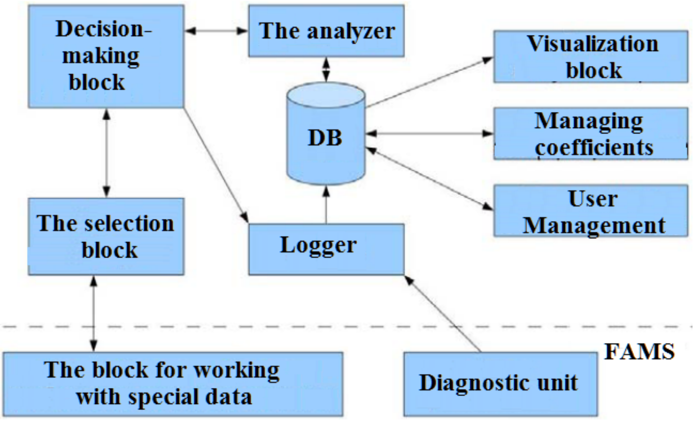

Figure 1. The general structure of interaction of the trajectory individualization subsystem with FAMS

The logger is designed to collect the necessary data and fill in the database. The concept of necessary includes information about the progress of states, answers to questions, test results, and the level of capabilities of objects. This unit also records the results of the analysis and the decisions made by the system.

The coefficient control unit is designed to change the coefficients corresponding to the object. The trajectory of the states changes non-linearly, and these coefficients determine the nature and magnitude of the changes.

The visualization block is designed to generate reports on the operation of the system, as well as to compile samples from the data collected by the logger. This information can be useful for operators, allowing them to see the dynamics of ongoing processes and events.

The analyzer processes information from the database and extracts the data necessary for making a decision from it.

The decision-making block. This block contains the main logic of the system. When an event occurs that requires processing, this module requests the necessary information from the analyzer. Based on the received data, a solution is generated and sent to the module that requested it, as well as to the logger for recording.

The selection block. This block is directly linked to FAMS and the decision-making block. It monitors the object and generates requests to the decision-making unit if the object has decided to go through the control phase. After receiving a response from the decision block, the selection block indicates the FAMS materials corresponding to the object level.

5. SOFTWARE INTEGRATION MECHANISMS WITH AIS IN THE CONTEXT OF CONNECTING EXTERNAL MODULES

AIS is a large and complex information system. Although it stores all its data in a database, it is better to interact with it through special interfaces. Thus, if we want to interact with AIS in one way or another, then it is necessary to implement a module that will provide the necessary functions and be equipped with an interface. The capabilities of the base class have their own rather narrow scope and do not allow access to all the functions and data of the IC. But this can be done by connecting the necessary libraries in the implemented module.

These libraries can be logically divided into several parts.

A library of authentication functions. This library includes functions and methods of interaction with the authentication and authorization system. Also, the functions of this library make it possible to determine whether the user is authorized and what privileges he has in the system, which makes it possible to implement access control in his module.

An abstraction layer for working with the database. Since this FAMS is quite extensive and stores a large amount of data in its database, a special abstraction layer has been created to access them, which allows you to get the necessary data using a function with a telling name. If it is necessary to modify any data, this software layer makes changes taking into account the relationship of various information from different database tables. All this in total allows you not to waste time on a detailed study of all the relationships between the data, but to focus on developing the required program code.

A library for working with questions. Since AIS is FAMS, it naturally has its own special data storage. Tools are also available to work with them. This allows you, if desired or necessary, to develop your own testing modules that differ from the original.

The library for working with files provides a relatively simple software layer for working with files. There are several possible ways to add files to AIS:

- saving to the cloud in a specially designated place;
- adding a link to download a file from another server.

The library makes it possible to work from the module under development with any of the types presented, abstracting from their different nature.

When solving the problem of integrating an automated trajectory control system with AIS, a number of problems arise. Along with writing the module, you should also consider the integration of information components. The initial database structure of the trajectory management system is shown in Figure 2.

It has several tables that overlap with similar ones in AIS in terms of semantic and partly informational load. In order to avoid duplication of information, it is necessary to semantically link both databases. There are two possible ways of implementation, each of which has its advantages and disadvantages:

1. Full integration with AIS, i.e. adding additional fields to the AIS tables necessary for the operation of our module. In this case, the database structure is shown in Figure 3. There will be problems with porting to the latest versions of AIS.

2. The module being developed as an add-on to the AIS. In this case, we bind to users, groups, etc. in the AIS database; the resulting database structure is shown in Figure 4.

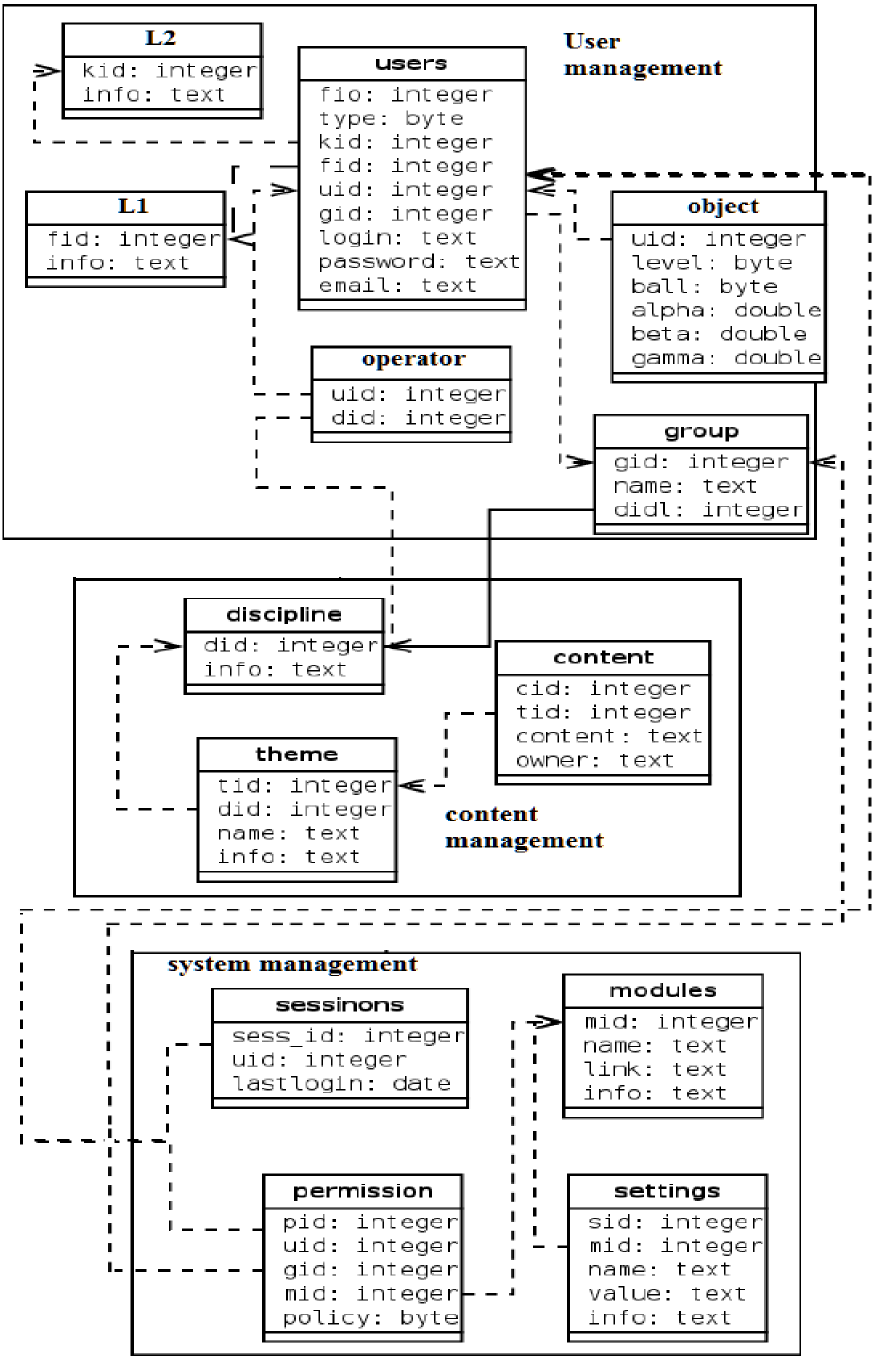

Figure 2. The database structure of the trajectory control system

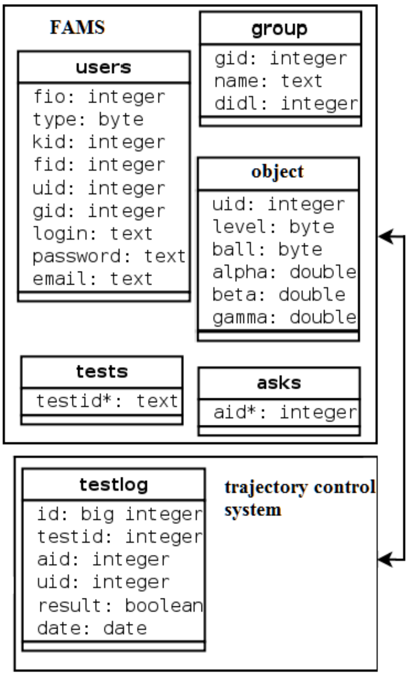

Figure 3. Database structure when two projects are completely merged

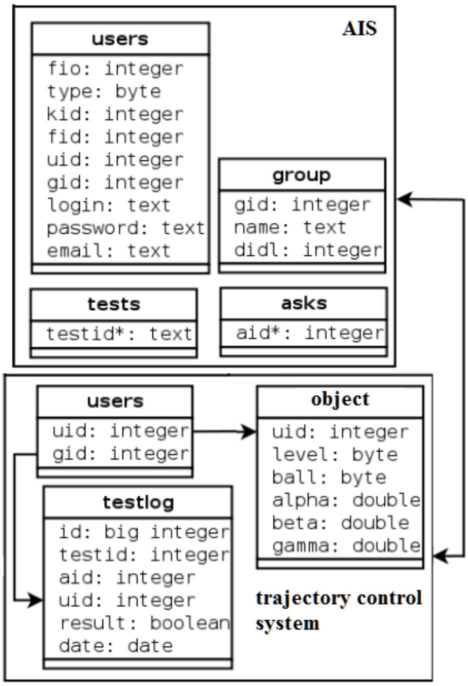

Figure 4. Database structure in case of partial merging of two projects

6. CONCLUSION

The purpose of the work was a reasonable automation of adaptive control of complex objects and trajectories in artificial intelligence systems. The elements of methods and technologies for adapting means of identifying the current state of objects in the formation of content, forms, means and methods of management in order to build an individual trajectory of states using artificial intelligence technologies are considered. It is shown that one of the options for calculating the current target level of an object, suitable for subsequent use in an automated system for constructing an individual trajectory of states, is to set the level as a linear convolution of parameters using normalized weighting coefficients in the form of an integral additive objective function. The components of the trajectory control software system are analyzed. The state trajectory management system is an add-on to the state management system and implies that the latter should have mechanisms for interacting with external software. The mechanisms of software integration with an artificial intelligence system in the context of connecting external modules are investigated.

REFERENCES

[1] Zhou Y. et al. Spatiotemporal Optimal Trajectory Planning for Safe Planar Manipulation of a Moving Object. *IEEE Transactions on Industrial Electronics*, vol. 8, 2023. DOI: 10.1109/TIE.2023.3301512.

[2] Morgan A.S., Hang K., Dollar A.M. Object-Agnostic Dexterous Manipulation of Partially Constrained Trajectories. *IEEE Robotics and Automation Letters*, vol. 5, no. 4, 2020, pp. 5494-5501.

[3] Stepanyan I.V., Lednev M.Y Prediction of the trajectory of the tracking object based on adaptive controller. *IOP Conference Series: Materials Science and Engineering*, vol. 747, 2020, p. 012078. DOI: 10.1088/1757-899X/747/1/012078.

[4] Zhang P. et al. A Multi-Object Tracking Approach Combining Contextual Features and Trajectory Prediction. *Electronics*, vol. 23, no. 12, 2023, p. 4720. https://doi.org/10.3390/electronics12234720.

[5] Lvovich K.I. et al. Modelling of Optimization Process of Personnel Adaptation to Digital Management in Organizational Systems. *International Journal on Information Technologies and Security*, vol. 13, no. 4, 2021, pp.71-82.

[6] Oleinikova S.A. et al. The General Scheme of the Genetic Algorithm for Solving the Task Scheduling Problem for a Multistage System and Assigning Time for Jobs. *International Journal on Information Technologies and Security*, vol. 13, no. 4, 2021, pp. 47-58.

[7] Liang Z.-G., Jiang Y.-H. The Calibration of Artificial Intelligence. *Jiliang Xuebao/Acta Metrologica Sinica*, vol. 42, no. 1, 2021, pp. 78-84.

[8] Rajanayagam H. et al. Effect of design variation in behaviour and performance of Endplate-Type intermodular connection. *Structures*, vol. 56, 2023, p. 104899. DOI: 10.1016/j.istruc.2023.104899.

Information about the authors:

Denis Igorevich Mutin – Dr.Sc. (IT), professor of Moscow State University of Technology “STANKIN”, Moscow, areas of scientific research - information technologies, computer networks, system analysis, optimization

Alexey Fedorovich Kaperko - Dr. Sci (IT), professor of National Research University Higher School of Economics, Moscow, areas of scientific research – control systems, sensors, system analysis

Sergey Aleksandrovich Sorokin – Dr.Sc. (IT), professor, Research Institute of Computing Complexes named after M.A. Kartsev, Moscow, areas of scientific research – system analysis, optimization, simulation of complex objects

Dmitrij Vladimirovich Sotnikov - postgraduate student, Voronezh State Technical University, areas of scientific research – Big Data, information systems, simulation of complex objects

Igor Victorovich Atlasov - Dr. Sci (Phys.-Math.), professor of Moscow University of Ministry of Internal Affairs of Russian Federation named by V. Ja. Kikot, Moscow, areas of scientific research – system analysis, optimization, simulation of complex objects

Nikita Alexandrovich Ryndin - Dr. Sci (IT), professor of Voronezh State Technical University, Voronezh, areas of scientific research – control systems, system analysis, optimization

Manuscript received on 28 December 2023