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METHODOLOGICAL ASPECTS OF OPERATIVE CONTROL SYSTEM INTELLECTUALIZATION FOR DYNAMIC OBJECTS

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Abstract. The problems of intelligent control system organization are considered: determining the number of intellectualization levels, the sequence of actions required for analysis of the control process, adding to the control system new elements providing for enhancement degree of its intellectualization, special features of its structural organization, estimating the possibilities of intellectualization, providing examples of practical intellectualization. The primary purpose of the study is to determine the purposeful organization of intelligent control systems as well as the necessity and usefulness of systemic consideration that takes into consideration the following: requirements of the problem statement, characteristics of the environment, means for acquiring and processing necessary information, working control mechanisms, functional characteristics and experience of user-operator. As a result of the analysis performed, characteristic levels of the intellectual development of a system were determined, the stages of performing intellectualization of a control system were proposed, and the effectiveness of proposed solutions for practical problems was shown.

Keywords: control system, intellectualization, organization of control systems, intelligent control, man-machine systems.

INTRODUCTION

The urgency of the problem of control system intellectualization is determined by the modern requirements to development and implementation new control systems for dynamic processes and systems that could use large volumes of informational data and are capable to perform intellectual processing of the data to reach high quality control in real time. Dynamic modern development of the computational means and particularly the means for parallel data processing like graphical and tensor processors as well as new intellectual data processing methods create favorable conditions for reaching high quality control. Together with the possibilities mentioned the requirements regarding data optimization are preserved aiming to determining the confidence intervals and characteristic numbers.

The complex approach to taking into consideration the purposeful functioning of a system, to determining dimensionality of complex systems characteristics and control environment, to description of functioning machine operator provides creating conditions in the direction mentioned.

The trend to automatizing of all sides of human activities (transportation, industrial production, agriculture, economy, home activities, social sphere etc.) require development of high-tech systems with intellectual functions, capable to interact with distributed data systems and use remote services.

The paper contains methodological aspects and examples of organizing intellectual control systems for complex dynamic objects and processes. It is also proposed the methodology for organizing control systems with functional structures that implement some separate characteristics of intellect.

Intellectual technology, intellectual control, intellectualization – all these notions are mostly accepted intuitively. When transition occurs from some purposeful functioning of a system to the process that exhibits intellectual features, then different subjective opinions come to being that gradually transform into the processes of search for high quality solutions and more complicated tasks.

The considerations proposed in the study are linked to emergence and development of natural evolutional intellect but the possibilities are preserved for hybrid combinations with other approaches. The intellectual level of a control system is linked to effectiveness of its functioning but there is no one-to-one correspondence. The general estimate of effectiveness of the system created and the measure of its intellectualization is rather relative and can be determined via investigating of its functioning using various methods in natural conditions or via computer simulations. The qualitative estimation of control system intellectuality supposes availability of some definite structure as well as adaptation of the structure and model parameters, memorizing control actions and their results, the possibilities for constructing models of environment and the system under study etc. The quantitative estimation of intellectuality can be expressed by the number of micro-situations in which within limited time can be found solution for stated problem. Time is a critical factor that influences general effectiveness of practical functioning of a system being studied. The effectiveness of a system is often considered as necessary initial but not sufficient condition of intellectuality. When strict conditions on the decision making time exist the effectiveness of general functioning of a control system that has lower intellectuality level may become higher. Certainly here we have to higher numerical effectiveness criterion.

PROBLEM STATEMENT

The use of conforming to the laws of evolutionary development biological systems for constructing engineering systems is carried out during all history of mankind. Development and improvement of intellectual functions of biological system stands in the same position, i.e. this is not exception. Here it is proposed to use basic natural conforming to the laws intellectual developments for creating technical systems though we don't remove the possibilities of using effective engineering solutions in hybrid systems. Development of such engineering systems requires paying special attention to selecting and processing only necessary information for solving specific goal problems and further usage of the data received.

One of key moments of carrying out analysis while solving complex practical problems and touching upon determining characteristics related to confidence interval and control of dynamic objects is taking into consideration and coordination of used environment characteristics and the controlled object with the goal requirements and possibilities of receiving information from gauges that is limited in its precision in noisy conditions as well as taking into consideration discrete time intervals for making control decisions. As an example, the problem is considered to control flying object in such a way to lead it into given limited space from the space of initial states. Taking into consideration of such requirements provides the possibility for carrying out micro-situational analysis and find operative control, to determine the areas of reachability for the goal values of variables and parameters for various control algorithms, and make conclusions regarding effectiveness of the usage for the algorithms applied.

Today there exist a large number of studies directed to description of intellectual features of biological systems and their implementation in technical systems [1, 2]. Of particular popularity and success today has the use of analogs for neural nets [3]. Practical implementation of intellectual systems is performed in the most diverse spheres of human activities; it is especially topical and substantiated problem for the unmanned transportation systems [4]. The problem of practical implementation of the intellectual systems is mainly related to the high dimension of input data, availability of noisy components, uncertainties in internal and external parameters of control processes as well as in absence of effective basic control solutions and structures that could be modernized. The systematic considerations of forming intellectual features of biological organisms helps to overcome the difficulties mentioned in the practice of creating and implementing intellectual technical systems.

Using quite generalized considerations it is possible to analyze the process of forming some system with control structures and control object in chosen goal environment as gradual refinement of the system organization.

The system that performs definite goal task is functioning in a specific selected environment and basically presents a part of the environment, and it can serve as external sphere for some other systems. The structural division of the sphere and system, of an object and control system can be quite conditional, that could be used for logical understandable description of the processes related to functioning of the system.

Selection of the goal environment is performed with taking into consideration the specificity of the problem being solved. Out of the world where everything is happening the part of environment is selected in which the specific task is implemented. Then the dimensionality of substantial characteristics and states of the goal environment is determined, selection of the controlled object, control system, input and output data, conforming to the laws functioning of a man in the process of search the goal solutions. Then the goal situations are described and determining of the sets of goal micro-situations that create situations, and it is determined the goal functioning in the situations and micro-situations.

The search of decisions necessary for reaching the goals determined in selected situations and micro-situations can be characterized as determining the function of data for output variables at the inputs of the goal (under investigation) system (for example, control system or decision support system). Taking into consideration the evolutional development of biological systems determine the basic directions of their improvement and further development in the sense of enhancement of the level of intellectual possibilities without strict division on availability or absence of intellect. In the problems that are solved by simple biological organisms the similarity of intellectual features can be highlighted by the specificity of subsystems receiving and processing external information (intellectual sensors). Further enhancement of the intellectuality level is linked to constructing of environment models and models of possible behavior of an object (being studied) in this environment with estimation of final results.

When intellectual control system is synthesized the attention should be paid to the urgent methodological questions related to selection and processing input information. Here also the aspects of constructing distributed control structures and databases as well as the questions of decision forecasting in the nonlinear non-stationary environments should be taken into consideration.

THE CONCEPTUAL IDEAS REGARDING ORGANIZATION OF INTELLECTUAL CONTROL SYSTEMS

When intellectual control system is synthesized it is necessary to take into consideration a series of general structural and functional norms. The norm touching upon adequate reflection of features of living beings and a man in the structure and functions of modules and systems being developed should be necessarily considered. The basic structural and functional similarity is reflected through development of logic-and-dynamic models of control processes. Extended functional similarity is reflected through constructing the models of adaptive and optimization stochastic transforms of control processes.

Consider the idea of compact discrete representation of the recognition processes and object control. Such representation supposes selection of substantial variables, forming of input and output spaces of features, the measure of discretization, and optimal division for specific control environment.

Now consider the idea of finding compact transforms that provide for optimal solution and correspond to representations of man-operator and experts. In particular, here it is necessary to perform processing of several data streams with their mutual comparison in functional space, and perform the goal transforms with several levels of decision making based only on the short time forecasts, but also estimate development of situation on the long-term time intervals.

The intellectual integrated control represents multicomponent process of searching for solutions that supposes forming of a series of goal images for control object and control environment, their further refinement, transforming and consolidation in the generalized goal space.

The control process is related to discrete or situational ones. The intervals of discretization or situations are determined by the interactions of control object and control subject as well as influence of environment. Here the most substantial influence on the discretization of control process makes man-operator and correspondingly his characteristics and practical experience. The next substantial reason for control process discretization is availability of noisy components in the control system and environment. Another factor influencing discrete characteristics of the control process is related to bad quality of data characterizing initial and current characteristics of controlled object and control environment. A specific feature of this representation is also taking into account of interaction between man-operator and controlled object even if the control is performed in fully automatic mode. Here automatic control is constructed with taking into consideration of man-operator representation about possible control process and his experience of work in conditions of preserving monitoring functions and correction of possible control decisions. Thus, the decisions that are performed (implemented) are directly or indirectly related to representation of man-operator and his conformity of laws regarding information transforming. Here it is of particular importance for development of separate optimal systems have the goals set by man-operator and their actual practical implementation.

The process of system intellectualization is considered as gradual enhancement of its possibilities regarding effective goal stated functioning on the extended set of environment states. We can state that when the control system reaches some goal using its actions more effectively than without such activity, then there exists some level of its intellectuality.

As an example of possible representation of the development levels for intellectual characteristics of automatic and automatized control systems the following levels are given:

1. The intellectualization level at which preliminary data processing is performed in a single control channel. For example, it can be the case of using specialized goal sensor or the system based upon directive control.

2. The intellectualization level at which several information channels are working and extra preliminary data processing is performed together with selection of substantial data necessary for reaching the goal. It is also performed identification and taking into account of possible uncertainties.

3. The intellectualization level at which development of information transformers is performed that take into account stable conformity to the laws of man-operator activities like logical inference or stereotype behavior.

4. The level of intellectualization at which adaptation is performed to the specificity of accepting and search for solution of the specific operator, the generation takes place and expansion of possibilities for selecting alternative information transforms.

5. The level of intellectualization at which during the control processes is taken into account the set of data- and knowledge bases about control object and environment; the adequacy is observed about system functioning according to basic notions and criteria with the man-operator what can be considered as initial level of image-like control.

6. The level of intellectualization at which exists adequacy of control system functioning according to the image representation of situations by the man-operator and decision forming by the technical part of the system in the definite specific control area.

7. The intellectualization level at which there exists adequacy of system functioning according to the basic information data (and outside of separate specific control area). Here is performed in concordance with multiple situations interaction of a man-operator with the engineering part of the control system.

8. The level of intellectualization at which the systems under study exhibit the characteristics of creative development and refinement.

ORGANIZATION OF GOAL REACHING SYSTEMS

The conformity to the laws for organizing goal reaching systems is expressed in structural and functional characteristics of highly organized living beings [5]. Analysis of these characteristics allows for determining the following basic conformities to the law.

Availability of some time and space continuum for the control system existence in the form of a part of selected environment.

Availability of definite levels of external and internal activities, and freedom of the system under study.

Availability of signals of definite levels for control and interaction of the system with environment and control of internal states.

The number of distinctive signal levels allows for selection of a limited number of possible states in the system and states of the system in the environment.

Availability of initial structural organization that determines initial choice of possible system reactions to external and internal influences.

Availability in the initial structure of motivation basis (for example, for satisfying of the life necessities as well as role necessities and self-development) that is expressed in the form of definite behavior or program of actions.

Availability in the initial structure of plastic elements that allow for recording stimuli signals, emergence of initial reactions and results of system interaction with the environment.

Availability of hierarchical structural system organization that determines interactions of its basic structures, motivation basis, plastic elements and the elements that are responsible for actualization of system reaction.

An example of the sequence of organization and search for the solutions in goal set man-machine systems:

- General formulation of the goal settings.
- Selection of the goal space characteristics and control object.
- Activities analysis of a man-operator under realization of various general and specific goal settings.
- Analysis of selected environment in the space of goal set functioning of a system – goal set reduction of the control environment.
- Analysis of the control object in the space of goal-set functioning of a system – the goal set dimension reduction of control object.
- Creation of a basic structure of a control system in realization of goal settings.
- Distribution of information and control system resources directed to effective and reliable realization of goal settings.
- Creating of possibilities for database and knowledge base expansion, adaptation, learning and repeated learning while realizing of the goal settings.
- Multilevel integration of resources and structures for generating decisions.
- Reaching integrated functioning of technical part of a control system and man-operator.
- Introducing into integrated goal system the features of creative developments.

ORGANIZING DISTRIBUTED REMOTE CONTROL SYSTEMS

Development of effective distributed remote control systems includes the following stages [6].

The problem statement formulation for remote control and determining requirements to the functional characteristics of control object and control system itself.

Formulation of specific temporal requirements to functional agents that are selected in the functional structure of control system under study.

Determining of characteristics for the existing structure of the net that can be used for solving the specific problem of related to remote control.

Determining of time delays emerging during the use of different protocols for information exchange within the net hired.

On the basis of the analysis performed distribution of the control blocks structure at the remote object is performed and in the control system.

The functional optimization is performed of control for the remote system at the expense of extra knowledge about characteristics of the system and environment.

Adding to the net structures of new information devices for receiving and processing information.

Creating of a developing net infrastructure with adding new intellectual features and possibilities.

Extra development of net information exchanging protocols and organization of new channels for information input.

For effective functioning of control systems with distributed information and executive resources in multitask net structures it is necessary to perform complex integrated considering of all elements of the control process and taking into account of the following recommendations:

– distribution of control information according to its value regarding the control goals and acceptable transmission delays;

– determining of specifications for data transmission protocols and for different types of information;

– determining expediency of usage for different channels and routs of information transmission;

– setting priorities of data meaningfulness and the sequences of its transmission in the information structures;

– creating the structures that provide for duplication or excessiveness of the data being transmitted;

– determining of structure for distribution of functional modules of the system and control object depending on possible intervals of control signal delay.

Besides taking into account of systemic requirements to information transmission additional possibilities can be hired for organizing of control structures that take into account perspective methods of control for high speed dynamic processes and structures for distribution of control means on the object and control system. All this helps to improve substantially quality of control for dynamic systems [7]. Fig. 1 shows examples of control organization for remote dynamic objects.

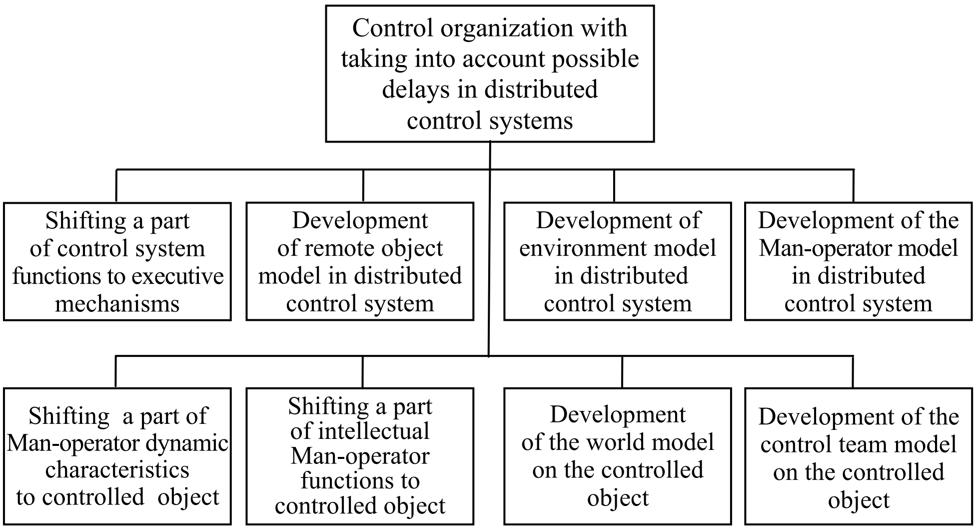

Fig. 1. Examples of control organization for remote dynamic objects

The complex usage of the methods developed for control of high-speed dynamic processes and taking into account of proposed recommendations regarding organization of information transmission in the distributed net structures allows for reaching general improvement of qualitative and quantitative effectiveness measures in the process of remote system control.

THE SYNTHESIS OF GOAL REACHING CONTROL OF A FLYING OBJECT IN CONFLICT AND ACCIDENT CONDITIONS

Consider example of constructing an airplane model and description of the airplane control in algorithms in the non-scheduled situations and equipment faults. Of high importance for successful solving of a flight safety problem are the questions of reliable and stable with regard to interferences of flight control when various goal maneuvers are performed. Also important are the questions of development control algorithms for providing the flights on an airplane with low stability reserve or in the case of unstable airplane.

The control algorithms being developed have to enhance the plane "vitality", reliability of its control system when maneuvers are performed. These algorithms also should provide for continuation of performing set tasks by an airplane when one or several control mechanisms exhibit fault regime. This problem can be solved at the expense of fault compensation by the control system thanks to reconfiguring of the control process by varying aerodynamic surfaces of an airplane.

Solving of the problems mentioned is proposed in the frames of a concept of constructing distributed control system. It is supposed that an airplane has various controlled aerodynamic surfaces, and control by executive mechanisms and surfaces can be performed separately. Flexible structure of control system provides the possibility for changing its configuration during flight, and use various functional regimes of aerodynamic surfaces to create aerodynamic forces of necessary configuration.

To reach stable movement of an airplane, automatic controllers for tangent angle, turn angle, and rove angle are used. The controllers should provide for reaching by airplane of the set orientation angle, performing maneuvers and the flight with given tangent, turn and roam angles. The automatic control of orientation angles provides for compensation of control mechanisms faults.

The algorithms development suggests on-board computer application in the control system. The on-board computer coordinates the functioning of control mechanisms and provides for performing in real time necessary computations and generation of control commands.

To solve the problems of performing goal tasks computer simulation of the control algorithms developed was performed for reaching the airplane control. To solve the simulation problem the flight of aerodynamically unstable airplane had been modeled in perturbed atmosphere. Simultaneously, it was modeled functioning of control system for aerodynamic surfaces of the airplane. Using the model created the testing of functioning of the algorithms developed was performed. The model developed allows for performing simulation of various modes and stages of flight as well as receive estimates of effectiveness of the algorithms functioning. The simulation allows for receiving information about possibilities and areas of application for each algorithm and control system as a whole.

Generally, the perturbed or controlled movement of an airplane is taking place in three-dimensional space because here simultaneously are taking place changings of parameters and variables that define direct and side movement.

When the amplitudes of parameter changings related to the movement of an airplane are small then equations of direct and side movement of the plane can be approximately studied separately. However, when the movement parameter changings are quite large such separation of the equations into direct and side movements starts to produce unacceptably large errors, and it is necessary to analyze complete system of equations describing spatial movement.

Development of the airplane dynamics model was performed on the purpose of simulation of various flight regimes and functioning of control system. To reach this goal complete system of equations describing spatial movement of an airplane was used.

The airplane movement takes place under influence of aerodynamic forces and moments produced by engines and gravitation forces. Generally, to define an airplane movement it is necessary to solve the following problems [8]:

– to find angular and linear velocities of an airplane movement, induced by the influence on it of all mentioned forces and moments;

– to determine the angles of the plane orientation relatively the flow that meet it, and coordinate axis linked to the Earth;

– to determine the shift of an airplane with respect to Earth.

Each of these tasks is supported by special set of differential equations. The model uses quite complete and precise equations of an airplane movement for performing necessary computations and allows for achievement of truthful results for modeling control system functions. In this case an airplane is considered as absolutely rigid body

The mass and inertia moments of airplane are considered as unchangeable during the time of modeling the plane and correspond to initial state of equilibrium flight.

It is also suggested that the plane configuration has symmetry plane and its masses are distributed symmetrically with respect to this plane.

To represent the movement model of unstable flying apparatus in three-dimensional space the work regarding development of stabilizing algorithms of the apparatus has been carried out with taking into consideration cross-channel links in the maneuvers are performed it is supposed that various external disturbances exist such as wind, atmosphere turbulence etc., as well as internal ones, such as poor precision of computations and sensors. To construct the trajectories of given movement into the goal area it is necessary to take into consideration the most substantial information characteristics of control object and environment, and have the possibility of continuous correction of the trajectory due to influence of random factors. Taking into account the general considerations given above, now present an example of control organization for flying apparatus at the stage of landing in accidental conditions and with influence of random wind changings.

Airplane control during the landing stage is the most complicated task of its control. That is why the problems of automation of airplane landing are given substantial attention. The system providing for the airplane landing for the case of engine fault has been developed as an compound part of integrated control system for complex dynamic objects that contains a program simulating movement of a flying apparatus in three-dimensional space.

The airplane landing in accident mode of engine fault puts ahead extra requirements to organization of functioning of interconnected system including pilot – automated control system – flying apparatus. Such systems, oriented to active interaction with man-operator in the extreme situation, should take into account specific features of the man-operator activities in such situations as well as accepting of incoming information by the man. This problem can be formulated as mutual coordination of goals and structure between automated part of the control system and activities of the man-operator. Such considering of a control system as integrated man-machine system can serve as a ground for determining general structure of control and for optimization of respective structural and functional solutions.

In the process of the system development it was accepted that man-machine system for controlling the object in critical regime of functioning requires taking into consideration for effective and reliable reaching the goals of control the following factors [9]:

– activity characteristics of a man-operator, special features of the process of accepting and processing the information by the man-operator as well as generating control actions;

– flexible structure of the algorithms developed and coordination of the algorithms structures with stable stereotypes of the man-operator;

– the possibility of operative switching the control functions between man and automaton;

– taking into consideration and compensation of various types and origin disturbances, dynamic analysis of situations, correction and synthesis of trajectories.

Computer simulation of the control algorithms developed using realistic airplane and environment model provided for the possibility of estimating effectiveness of reaching final goal in complicated navigation environment. For the task of emergency landing of a cargo plane it is possible to generate substantial enhancement of dimensions for the initial states area from which positive result can be reached in comparison with known trajectory control algorithms.

It was also developed and optimized regarding the types and content of control information the interface providing for interaction of a pilot with control system. The interface was coordinated with characteristics of the man-operator and his information requirements in critical situations.

ESTIMATION OF CONTROL EFFECTIVENESS

Estimation of decision effectiveness in general case should be received for the whole region of allowable initial conditions. As a rule the region is rather large and simple analysis (trying) of all points or variants requires substantial time and appropriate computational means. Taking into account the systemic methodology for specific realizations of a control process, generally, we managed to reduce the number of variants for determining effectiveness of analyzed decisions at the expense of considering continuity of the control process and conformity to the laws of systemic interactions. Continuity, as well as stability of the nature of control processes suggests that after changings in external conditions that influence the changings of object states, it is occurring relatively small change of final control. Usually, these values (changings) do not exceed some definite threshold in the limits of one given macro-situation. On the limit transitions between the situations (transition micro-situations) the control may change in the uneven form, and the changings in final results can substantially distinguish from inter-situational values. As an example of calculating such estimates it was considered control of the goal movement of an airplane with constraints regarding energy possibilities of the apparatus in perturbed environment. On the basis of control methodology considered above it was created a series of effective control systems for aviation and marine transportation means in complex navigation conditions, in conditions of equipment fault and strong influence of external disturbances.

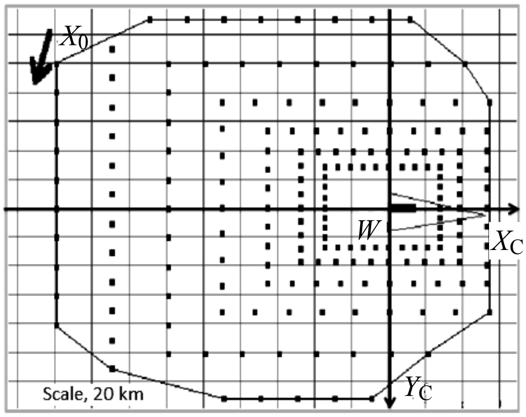

Fig. 2. The region of initial states for flying apparatus, from which successful landing is performed. The height echelon — 5000 m. Wind is favorable: X_0 — initial state of an apparatus; W — state of wind on the landing strip; X_C, Y_C — coordinate directions

Figs. 2–4 show examples of reachability regions for effectiveness estimating of control algorithms for cargo airplane, where the arrow indicates to initial course of flying apparatus, and sharp angle of the triangle points to the wind direction. The computer simulation of the control algorithms developed with realistic model of the airplane allowed for estimate effectiveness of reaching final goal in a complex navigation environment. The area of the initial positions of the airplane, from where a positive landing result is achieved, can be increased up to 2.5 times in comparison with the known methods of landing along a predetermined trajectory.

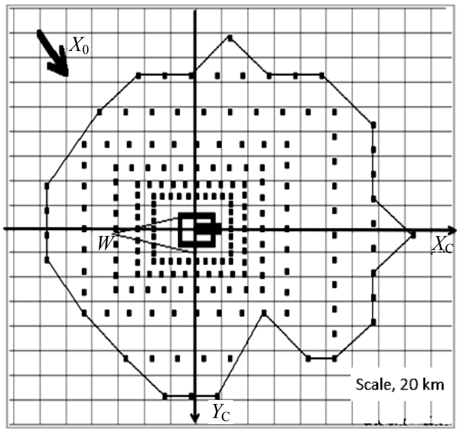

Fig. 3. The region of initial states for flying apparatus, from which successful landing is performed. Height echelon — 5000 м. Wind unfavorable: (X_0 — initial state of an apparatus, W — state of wind on the landing strip, X_C, Y_C — coordinate directions)

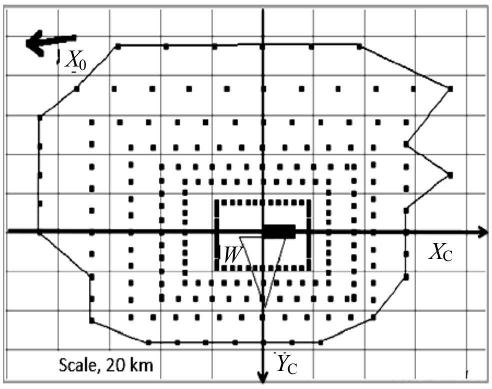

Fig. 4. The region of initial states for flying apparatus, from which successful landing is performed. Height echelon — 3000 m. Wind unfavorable: X_0 — initial state of an apparatus; W — state of wind on the landing strip; X_C, Y_C — coordinate directions

DIRECTIONS FOR PERSPECTIVE RESEARCH

The modern technical level of information processing tools and the experience of creating control systems capable of operating in automatic mode and effectively interacting with a person in critical situations makes it possible to identify promising areas of research and development.

It is proposed development of systems that include the sense notions, databases and knowledge bases, objects (systems) and their interactions (selected or general model of the world).

It is also proposed development of basic elements and processors that possess the features of adaptation, learning and repeated learning for organizing parallel data processing in stochastic environment.

We propose development of interaction architecture revealing actual interaction for modern computational means, basic elements and stochastic environment.

Development of structure and separate components for integrated and distributed control systems.

Reaching necessary level of automation various purpose of distributed databases and knowledge bases.

It is necessary to reach high quality of automatic and automated remote control for dynamic objects in real time.

Enhancement of intellectual possibilities of control systems and decision support systems with making use of distributed human and machine resources.

It is proposed development and application of hybrid man-machine intellectual complexes and systems for processing databases and knowledge data.

These are quite general directions that acquire in sophisticated up-to-date conditions special meaning. Development of multiprocessor computational means and cloud computing, storing knowledge and accessibility to large databases related to control systems and environments with making use of remote access provide for the new possibilities of creating modern control system with features of artificial intelligence. It is particular importance development and practical use of neuron-like structures and technologies of convolutional type and deep learning [3, 10, 11]. The active use of accessible databases related to various object types for neuron-like systems learning provided the possibility for getting results starting from 2014 of automatic object recognition that overcome the results of recognition received by man. On the basis of similar technologies new autonomous control systems are developed for transportation means, for machine translation using different languages, the systems for searching objects in the images and generation of their descriptions, the systems for autonomous carrying out dialogs in separate areas of activities, the systems for synthesis of stylized images, and many of other new developments.

CONCLUSIONS

In the process of organization of effectively functioning man-machine control system it can be distinguished the following basic stages of development control algorithms and structures.

First is the stage of creating adequate model of object and control environment. Here, it is necessary, as possible, to develop precise enough models. The limiting factors usually are the characteristics of environment noise, low observation precision of object variables, and impossibility to reach high precision of representation for complicated functional characteristics, available, for example, in the form of approximate table values.

On this stage the limit possibilities of a control object as a whole are studied, and the problems are solved touching upon stabilization of separate characteristics and development of automatic subsystems for them.

The second stage is usually devoted to development of basic control structure that is characterized by high stability and reliability of functioning. The structure has its specific logic of functioning for the basic set of realizable situations, logic of carrying out testing of basic nodes and logic for the usage of reserved and autonomous adaptive equipment.

The third stage includes development of means for representing control information and the means for monitoring functioning of the control system as a whole. For the second and third stages it is particularly important taking into consideration the goal requirements of a man-operator, his knowledge of functional characteristics of the system and the use of his former experience of work with typical control systems of definite class.

The fourth stage is devoted to implementation of extended matching of operator and control system in conditions of higher risk and non-trivial situations.

Besides, the possibilities are created for extended situational analysis and mutual adaptation between man-operator and control system being created.

The fifth stage is directed to providing for the control system with the means of interaction with man-operator using the language of natural representations and notions, providing the system with possibilities of realization creative elements of the control process.

The indicated general ideas regarding organization of intellectual control systems receive extended extra possibilities of implementation in modern engineering and informational conditions. Correct discretization of the information receiving processes, of the information transforming and control processes should be matched to the goal tasks of the system and interactions with man-operator. A detailed analysis of control processes on the relatively short time intervals (micro-situations) is coordinated well with the development of modern neural like systems in the form of multilayer high precision networks.

The appearance of new computational possibilities in the form of tensor processor and cloud services (computing), that provide for an access to such equipment, create new possibilities for introduction of intellectualization to information transformations and, consequently, constructing of intellectual control systems.

The practical development results are concentrated on control of moving dynamic systems, more precisely, on flying objects in critical regimes of flight.

It was also considered the problem of directing flying apparatus into given limited region with predetermined state characteristics in conditions of availability substantial external disturbances and limited control resources. The three-dimensional computer simulation model, environment and control algorithms were proposed that are distinguished by the high similarity measure with actual functioning of practically available systems.

The control algorithms developed are related well to the experience of pilots regarding control of flying apparatus in conditions of strong disturbances of various nature and with availability of substantial uncertainties in information data. These algorithms allow for making control decisions at each moment, construct optimal goal trajectory with taking into consideration current state characteristics of controlled object and environment.

The use of the micro-situational analysis and synthesis methods allows for automation in different spheres of practical human activities, especially in the directions where exist substantial uncertainties of data, and deficit of time for decision making.

The results achieved are directed to development of information technologies for the goal reaching systems of various classes, and have high practical meaning for solving wide class of problems regarding control of complex dynamic systems in the conflict and accident conditions. The results can also be applied in the analysis and anticipating of catastrophic events in economic and social systems and processes, in organizing of multilevel industrial productions in conditions of uncertainty and deficit of resources.

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МЕТОДОЛОГІЧНІ АСПЕКТИ ІНТЕЛЕКТУАЛІЗАЦІЇ СИСТЕМ ОПЕРАТИВНОГО КЕРУВАННЯ ДИНАМІЧНИМИ ОБ'ЄКТАМИ / С.В. Мельников, П.М. Малежик, А.С. Гасанов, П.І. Бідюк

Анотація. Розглянуто питання організації інтелектуальних систем керування: визначення рівнів інтелектуалізації, послідовність проведення аналізу складових компонентів процесу керування, унесення в систему характеристичних властивостей інтелекту, особливості структурної організації, оцінювання міри інтелектуалізації, приклади практичної реалізації. Метою розгляду є висвітлення напрямів організації інтелектуальних систем керування, необхідності і корисності системного розгляду, що враховує вимоги поставленого цільового завдання, характеристики зовнішнього середовища, використовувані засоби отримання, перетворення інформації і відпрацювання керування, функціональні характеристики і досвід роботи людини-оператора. У результаті проведеного аналізу виділено рівні розвитку інтелекту системи керування, визначено етапи проведення інтелектуалізації системи, показано ефективність викладених представлень для вирішення практичних завдань.

Ключові слова: система керування, інтелектуалізація, організація систем керування, інтелектуальне керування, людино-машинні системи.