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THE DEVELOPMENT OF HIGHLY RELIABLE SOFTWARE SYSTEMS

Annotation. The application of insertion modeling technology to the development of highly reliable software components of software critical systems is considered.

Key words: theory of interaction, insertion modeling, cyber-physical systems, verification, testing.

Insertion modeling technology [1] is based on the algebraic theory of interaction in multi agent distributed environments. We shall consider the application of this technology to create highly reliable software systems. High reliability requirements primarily relate to safety-critical systems. These systems especially include systems from aerospace and medical industry, nuclear energy and weapons production. Failures in these systems associated with the threat of life, loss of equipment, environmental destruction and so on. The process of developing highly reliable systems based on risk reduction or complete elimination of the violation of safety conditions in the system functioning. Safety critical systems include the modern cyber physical systems [2], which deeply integrate cyber (that is software) and physical (technical) components.

Software engineering of safety critical systems is based on the inclusion of verification and validation in the development process. Current methods require the use of formal verification methods for constructing mathematical models and generate test kits that provide maximum coverage program codes.

Reliability can be external and internal. External one protects against unauthorized interference, internal provides the absence of errors, the reliability and validity of internal interactions. Here we confine to the consideration of internal reliability.

Design and analysis of complex systems requires construction of formal models of different levels of abstraction at all stages of design and development. The use of formal models can detect incorrect decision error and impropriety in the early stages of development, which significantly reduces effort and saves money if these errors are detected in the later stages or in the resulting product.

In the insertion models a system is represented as a composition of environment and agents inserted into it. Environments and agents are represented as transition (dynamic) systems that evolve over time and have externally observable behavior. The behavior of agents and environments determined using equations in behavior algebra. Behavior algebra is continuous multisorted algebra and insertion of agent into environment changes the environment behavior through continuous operator. Continuity is understood relatively to complete partial order topology defined for the behavior algebra.

The main method of investigation of insertion models is a symbolic modeling of attribute environments. The states of such environments in symbolic modeling are predicate calculus formulas with quantifiers and software implementation of these models use symbolic system of automatic deduction.

Fundamentals of insertion modeling were laid in the late 90's in the works on the model of interaction between agents and environments, and practical use of insertion modeling refers to the early 2000s, when on the order of Motorola in the Ukrainian company ISS with the staff of Glushkov Institute of Cybernetics a system VRS for automatic verification of software systems requirements has been developed. Later the system was acquired by the American company UniqueSoft. On the basis of verification system new development and design tools has been developed, including means for testing and code generation.

Experience gained in working with foreign companies was used to develop the Institute of Cybernetics own insertion modeling system IMS, which has the means to create highly reliable software systems. In the developing of this system, fellow workers from Kherson State University are actively involved. IMS tools include tools for symbolic verification, test generation with almost 100% coverage of code, tools for program invariants generation, means of optimizing transformations, and refactoring of programs and their models. An important area of application of this technology is the parallelization of computational processes on multiprocessor computers and organization of high performance computing in network and cloud systems.

Source language of IMS consists of algebraic and logical means of describing the behavior of systems in conjunction with graphic languages MSC and UCM, belonging to ITU standards. The formal semantics of the language is presented using insertion models. It is used in the process of developing of IMS, providing high quality products.

The next goal of the development of insertion modeling is to adapt insertion models for the development of cyber physical systems. Currently the main mathematical models in this area are timed and hybrid automata. Now we developed a new model which generalize old models and is consistent with insertion models. This model is a semigroup transition system. The elements of semigroup of traces are used as actions and all transitions are equipped by duration – a number from the additive subsemigroup of semigroup of real numbers. Agents and environments are semigroup transition systems and attribute environment represents the evolution of physical components as well as the data structures of software components.

Now the tools for modeling, verification, and testing of insertion models of cyber physical systems are developing.

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MODEL ORDER REDUCTION OF THE LARGE-SCALE SYSTEM

Annotation. Significant for application reduction problem of large-scale time-invariant system to more simple small order is considered and developed in the report.

Key words: model reduction; approximation; optimization.

The problem of low-order approximating models construction for controlled and observable systems described in the state space by a large number of internal variables is relevant for many applications. Thus, with the help of a simpler description, it is possible to reasonably predict the behavior of output variables and synthesize simpler controls that provide the desired dynamic quality of the controlled systems.

There is a rather large number of publications devoted to this problem. Some of their review but far from complete may be find, for example, in [1, 2].

The model reduction problem was considered in the following treating. We have an initial description of a linear large-scale stationary state space system in the form

$$\dot{x} = Ax + Bu,\ y = Cx, \tag{1}$$

where the state vector x has a sufficiently large dimension N. The system (1) can be scalar when the input u and output y are scalar functions, or multi input multi output system with u and y vector-functions. In the latter case dimensions of these vectors are assumed small in comparison with N. The stated problem is: for the same inputs and outputs of the system construct a model in which the internal state vector would have a significantly smaller dimension. In this case, the output of the reduced model for any restricted input the same (identical) for both the original system and reduced models satisfies the condition

$$\|y - \bar{y}\| \le \varepsilon, \tag{2}$$

where a given small value ε is consistent with the restriction on the input. The norm in (2) is established by a specific problem.

Since a number of difficult problems arise in the solution of this problem in such a setting, a different approach to its formulation and solution is proposed. Instead of (1), we consider an equivalent description, which follows directly from the Cauchy formula for zero initial conditions

$$y(t) = \int_0^t C\Phi(t-\tau)\cdot Bu(\tau)d\tau, \tag{3}$$

where $\Phi(\theta)$ is the transition matrix, the elements of which are formed from independent fundamental solutions. It is advisable to approximate the matrix elements separately for each input and output. Then the problem is reduced to solving a sequence of problems with one input and one output independently.

Based on the theory of realizations, the impulse function in the scalar case can be written in the analytical form

$$y(t) = \int_0^t h(t-\tau)\cdot u(\tau)d\tau, \tag{4}$$

where $h(\theta) = \sum_{p=1}^{P}\left[f_p^c \cos\beta_p\theta + f_p^s \sin\beta_p\theta\right]e^{-\alpha_p\theta}$, $f_p^c = c_{mp}^c \cdot b_{rp}^c + c_{mp}^s \cdot b_{rp}^s$, $f_p^s = c_{mp}^s \cdot b_{rp}^c - c_{mp}^c \cdot b_{rp}^s$. The index m corresponds to the m-th output, and r corresponds to the r-th input. The case of multiple eigenvalues is eliminated for simplicity. The description (4) includes both systems with real and complex eigenvalues. Dimension P of the initial system is large.

In this approach, the parameters of the truncated model are determined from the optimization problem as minimization elements

$$\|\bar{h} - h\| \to \min , \tag{5}$$

and the dimension Q of the truncated model satisfying the condition $Q << P$ is found iteratively through the solution of the sequence of problems (5), in which Q is varied, starting, for example, with $Q = 1$. In addition to the variational it is proposed the approach based on the singular expansion of the Hankel matrix H formed from the discrete function of the impulse response. Expressions of this function through the parameters of the system (1) allow us to factorize the matrix and present it as a product of observability and controllability matrices. Using the SVD-decomposition of the Hankel matrix, it is possible to estimate the closeness of this matrix to matrices of incomplete rank by means of singular values and to represent it as a sum of two incomplete rank matrices $H = H_1 + H_2$. This, in turn, makes it possible to reduce the order of the model by the matrix H_1, which is made up of the most significant modes of the system. The representation of the matrix H_1 in the form of an SVD-decomposition allows one to obtain the expression for the matrix of observability and controllability of the truncated model for some realization. From these, the matrix A and the vectors b and c of the reduced model are determined.

Numerical modeling is used to study the methods described above. The dependence of the approximation error ε in (2) on the dimensionality of the reduced model is shown. A comparative analysis of both methods and computational features of various optimization methods are fulfilled in the report. Some questions of practical application of the results are discussed.

As a result of modeling it is established that each eigenvalue of a truncated model of a smaller order approximates a certain class of roots of the original system. Thus, reduction of the model order leads to some averaged values of the invariant parameters, and not just to truncation of the initial system with respect to these parameters.

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UNIFIED NATIONAL SYNCHRO-INFORMATION SYSTEM − HIGH-TECH INFRASTRUCTURE FOR AUTOMATED COMPLEXES

Annotation. Implementation of the proposed idea as a set of innovative tools that will work as part of the Unified National Synchro-Information System of Ukraine from the national time-scale reference sources is a real alternative to using foreign satellite navigation systems. The system will allow, due to the diversification of the digital transmission of clock signals, to provide information survivability and improve reliability.

Key words: automatic, info-communication, synchronization, system, synchro-information.

The rapid development of modern information technologies is characterized by the intensive use of reference values of the time and frequency for synchronous functioning of high-tech systems in the areas of defense, government cyber security and many other industries of Ukraine.

In Ukraine, there is a public service of reference time and reference frequencies that includes SE "Ukrmetrteststandard", that performs cross-regional and cross-industry coordination and execution of works aimed at ensuring the uniformity of time and frequency measurements [1]. Nowadays, the government service, despite generating and maintaining the national time scale at the level of the best world national scales, almost does not transmit the reference signals of time scale and frequency to the consumers by means of existing information channels. The existing technical means in Ukraine do not form a unified system and cannot satisfy the requirements of all consumers of time-frequency information. This encourages consumers to use synchronization information from other states and governments (for instance, from satellite navigation systems GPS and GLONASS), which creates a threat to national security and increases the risks of losing the uniformity of time and frequency measurements within the state. The main disadvantages of such satellite systems are dependence of their signal quality from non-deterministic characteristics of the open environment where radio waves are transmitted and, as well, the lack of protection against the intentional distortion of synchro-information.

Unified National Synchro-Information System of Ukraine (UNSIS) should serve to implement the processes of transporting information about a unified precise time, reference clock, time intervals so on for objects that need it (within the borders of the country) in order to ensure their coordinated, synchronous work [1-3]. With the implementation of the proposed idea, the conditions will be created for the information security of critical infrastructure facilities in the country and also practical results of dual use for government institutions will be obtained: The Armed Forces of Ukraine, GW "Derzhspeczv'yazok", SE "Ukrmetrteststandard" and others. Considering the above, it can be concluded that the issue of creating the UNSIS of Ukraine is of current importance.

Separately, the importance of obtaining reference time signals by special purpose services that solve the tasks of national cybersecurity of the government must be noted as well as the need to introduce a single (Kyiv) accounting and reporting time in the country.

The listed facts are weighty arguments for the need of creating UNSIS of Ukraine at the national scale.

Pointed necessity, importance and possibility of distributing quality synchro-information demand determining the priority of a mentioned innovative high-tech development direction and justification of the conceptual provisions of the construction of UNSIS of Ukraine taking into account the results of the research and deploying into production and operation of complex of domestic equipment for synchronization of telecommunication networks and information structures, which is competitive with the best world counterparts.

The proposed set of innovative tools will not only provide high-quality reference signals of united reference time but will also create conditions for effective synchro-information supply for other infrastructure facilities in the country with the minimal cost and will have practical results for dual use in The Armed Forces of Ukraine, improving government cyber security, due to building the UNSIS of Ukraine – modern autonomous land-based system, independent from foreign services of time and frequency.

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THE ESTIMATES OF INFLUENCE OF BOUNDED PERTURBATIONS ON NONLINEARDISCRETE SYSTEMS

Annotation. The report is devoted to calculation of interval invariant sets of nonlinear discrete systems. The radius of invariant sets is used as a measure of the influence of bounded perturbations on the systems.

Key words: discrete nonlinear dynamical systems, bounded perturbations.

Introduction

The radius of interval invariant set is considered as a major criterion of the quality of functioning of a dynamic system. The obtained solution to the problem in the form of radius of invariant set is applicable to a sufficiently wide class of nonlinear discrete systems.

The problem statement and the solution

Invariant sets of systems with two-sided linear constraints.

Consider the given class of discrete systems:

$$X_{n+1} = AX_n + f(X_n)B + Z_n, \tag{1}$$

where $X_n \in \mathbf{R}^m$, A is an $(m\times m)$ matrix, $B^T \in \mathbf{R}^m = (1, 0, \ldots, 0)$, $Z_n \in \mathbf{R}^m$ is a perturbation with the given a priori estimate:

$$Z_n \in \mathbf{Z} = \left\{ Z : \|Z\|_\infty = \sum_{i=1}^{m} |z_i| \le \sigma \right\}. \tag{2}$$

The values of function $f(X_n) = f[\sigma(X_n)]$, where $\sigma(\cdot) = C^T X_n$, are considered to belong to the cone of the first order:

$$f[\sigma(X_n)] \in \varphi(X_n) = \varphi^+(X_n) \cup \varphi^-(X_n);\ i = \overline{1;m}; \tag{3}$$

where

$$\varphi^+(X_n) = \{\sigma(\cdot) : \underline{k}\sigma(\cdot) \le f(\cdot) \le \overline{k}\sigma(\cdot)\} \text{ if } \sigma(\cdot) \ge 0; \tag{4}$$

$$\varphi^-(X_n) = \{\sigma(\cdot) : \overline{k}\sigma(\cdot) \ge f(\cdot) \ge \underline{k}\sigma(\cdot)\} \text{ if } \sigma(\cdot) \le 0. \tag{5}$$

Assuming $X_n \in \mathbf{X}_n$, the system (1)-(3) is described by the nonlinear difference inclusion:

$$X_{n+1} \in \mathbf{X}_{n+1} = \bigcup_{\substack{X_n \in \mathbf{X}_n \\ Z_n \in \mathbf{Z}}} [AX_n + \varphi(X_n)B + Z_n].$$

We approximate this set by the minimum-volume interval set [1] and obtain the equation $\overline{\mathbf{X}}_{n+1} = \Gamma(\overline{\mathbf{X}}_n) + \mathbf{Z}$. Substitute $\overline{\mathbf{X}}_{n+1} = \overline{\mathbf{X}}_n = \overset{*}{\mathbf{X}}$ into this equation and find the solution of equation:

$$\overset{*}{\mathbf{X}} = \Gamma(\overset{*}{\mathbf{X}}) + \mathbf{Z}. \tag{6}$$

The solution $\overset{*}{\mathbf{X}}$ to equation (6) is an interval invariant set with the radius:

$$r(\overset{*}{\mathbf{X}}) = \max_{X \in \overset{*}{\mathbf{X}}} \left(\|X\|_\infty = \sum_{i=1}^{m} |x_i| \right),$$

i.e., a set, which satisfies the condition, if $X_n \in \overset{*}{\mathbf{X}}$ then $X_{n+1} \in \overset{*}{\mathbf{X}}$ with all feasible values of Z_n within the bounds (2).

It is proven that the description of family of linear systems:

$$X_{n+1} = (A + kBC^T)X_n + Z_n, \text{ where } \underline{k} \le k \le \overline{k},\ Z_n \in \mathbf{Z},$$

is equivalent to the description of systems (1), (2), (3).

Invariant sets of systems with two-sided nonlinear constraints. Consider the same class of systems (1), (2) with the function $f(x)$, which satisfies the constraints:

$$\underline{k}\,\overset{*}{f}(\sigma_n) \le f(\sigma_n) \le \bar{k}\,\overset{*}{f}(\sigma_n)\,, \tag{7}$$

where $\overset{*}{f}(C^T X_n = \sigma_n)$ is a given function. The given inequalities (7) mean that we deal with the multivalued mapping:

$$f[\sigma(X_n) = \sigma_n] \in \eta(X_n) = \{\sigma_n : 0 < \underline{k}\,\overset{*}{f}(\sigma_n) \le f(\sigma_n) \le \bar{k}\,\overset{*}{f}(\sigma_n)\}. \tag{8}$$

$$f[\sigma(X_n) = \sigma_n] \in \eta(X_n) = \{\sigma_n : 0 < \underline{k}\,\overset{*}{f}(\sigma_n) \le f(\sigma_n) \le \bar{k}\,\overset{*}{f}(\sigma_n)\}. \tag{8}$$

The dynamics of the family of systems (1), (2), (7) is described with the nonlinear difference inclusion:

$$X_{n+1} \in \mathbf{X}_{n+1} = A\overline{\mathbf{X}}_n + \eta(\overline{\mathbf{X}}_n)B + \mathbf{Z}\,. \tag{9}$$

The general approach to calculation of invariant set for the system (9) remains the same as above.

Conclusions. The report concerns calculation of the radius of invariant set as measure of influence of bounded perturbations on nonlinear dynamic system for the two common cases, i.e., with either linear or nonlinear two-sided constraints on the values of nonlinear functions. In both cases, a constructive solution to the problem is obtained in the class of interval invariant sets. The resulting combinatorial optimization problems of a low dimensions can be solved efficiently by a direct search.

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PECULIARITIES OF AUTOMATION OF BIOTECHNICAL OBJECTS'SYSTEMSIN AGRICULTURE

Annotation. Agrarian sector of the economy of Ukraine is filled by modern high-tech enterprises, where the share of power engineering in structure of the cost price of produced goods reaches 70%. Typical automation systems used in such enterprises do not provide high energy efficiency. To solve this problem it is proposed to use intelligent algorithms for the formation of management for electrical complexes strategies, that are the components of technology and the implementation of these algorithms.

Key words: poultry farms, greenhouses, biological filling, automation systems, intelligent control systems.

Even in face of high energy prices, the agrarian sector of Ukraine's economy demonstrates promising results of efficiency. This is especially noticeable for industrial enterprises – hothouse combines, poultry farms, etc., where a large volumes of energy flows are used. In such enterprises the share of manual labor significantly reduced, that positively affects also the quality of products. At the same time, there are opportunities for increasing the energy's efficiency of such enterprises, because in structure of the cost of produced goods, the share of energy reaches 20-70%.

In now days, systems that shape strategies of management for electrical complexes, that are components of technologies, implement in poultry farms and hothouse combines the simplest positional stabilization algorithms, that do not allow to provide the highest profit of the enterprise at current moment. This is due to fact that in such automation systems, the results of analysis of the following phenomena are not used: stages of biological filling (plants, poultry); natural disturbance (temperature and humidity of the environment, solar radiation, etc.); pricing policy in market goods (prices for: energy, projected production, services rendered, etc.).

According to biologists' research results, it is known that states of birds in poultry houses and plants in closed-soil structures depend on parameters of atmosphere – temperature, humidity, gas composition, intensity and spectral composition of illumination (with use of zootrons and phytotrons, the values of these parameters, that provide the highest productivity of biological content, are established). It is clear that feeding of birds and plant's nutrition should be carried out in accordance with the requirements of technology. In conditions of cheap energy resources, stabilization of technological parameters in any technological period gave a good result, because the most important thing had an amount of produced goods. However, the 90s of the previous century were characterized by rising of prices for energy, which led to development and use of optimal algorithms of flow energy's control and made it possible to reduce energy costs in structure of the cost price of produced goods by 3-4% [1].

Results of the study of biotechnical objects allowed to make conclusion that their dynamic characteristics in production process are significantly changing, that does not allow to ensure optimal functioning of automation systems. Due to this fact, adaptive systems have developed, that made it possible to reduce the share of energy in structure of the cost of produced goods by 6-8%.

As already noted, states of living organisms are determined by parameters of building's atmosphere, where they are located – temperature, humidity, gas composition of air, lighting. The latter is especially important for plants that are kept in buildings of closed-soil – without illumination there is no photosynthesis, and hence there is no development of plant. Significant influence on these parameters is made by the external environment – natural perturbations in form of changes in temperature, humidity, solar radiation. Economic feasibility of compensating of these effects is determined by results of analysis and forecast of natural perturbations, states of biological filling, pricing policy in market of commodity and reliability of obtained result. This task is implemented by intelligent systems of management that operate on the base of knowledge, filled by information about:

living organisms, patterns of natural perturbations, prices for energy and for produced goods and rules for the use of this information. The base of knowledge is realized using such theories as: random processes or neural networks for the analysis and forecast of natural disturbances; games and statistical decisions to make optimal decisions about management strategies. By usage of such systems it is possible to reduce energy costs by 10-12% [2].

Usage of robotics to monitor plants and atmosphere in closed-soil facilities is prospect in now days. The mobile robot moves through the greenhouse space, cramming obstacles and minimizing energy costs. Information about plant's state, including quality of plant products, is used as a feedback for central system of automation, that provides the formation of optimal management strategies (profit is used as criteria of optimization). And in this case the solution of problem of orientation in space of greenhouse, processing and transmission of received information is carried out by using intelligent algorithms [3].

Ukraine is one of the main exporters of grain in the world. In conditions of constant increase of prices for fertilizers (without them it is impossible to achieve high yields) the task of their operational and rational usage becomes urgent. Requirement of efficiency is explained by limited time of mineral fertilizer's application in process of plants' vegetation. Solution of such a task is possible by monitoring in a visible spectrum of grain crops' plantations, using for this purpose flying robots with camera. Long-term experiments with the use of phytotron and soil facilities made it possible to determine rational flight modes' robot and camera settings to get work shots. Spectral analysis of photos considering calibration lighting has made it possible, on the basis of the use of intellectual algorithm, to assess plants' needs for nutrition's elements regarding geographical coordinates. Above mentioned gives the opportunity of operative application of appropriate amount of mineral fertilizers for obtaining of planned yields.

Conclusions

1. Usage of traditional stabilization algorithms in automation systems under conditions of high cost for energy resources makes such systems and enterprises energy-inefficient.

2. Usage of intelligent systems of control for electrical systems, operating on the basis of knowledge base, allows:

- to substantial increase of energy efficiency of such systems, reducing energy consumption by 10-12% comparing to traditional stabilization positional algorithms;
- to increase of efficiency of decision making about the necessity of mineral fertilizer application for planting regarding geographic coordinates.

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Section 1 “Mathematical problems of control, optimization and games theory”

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TOTAL WEIGHTED TARDINESS ON ONE MACHINE: A HEURISTIC ALGORITHM BASED ON THE PSC-ALGORITHM

Annotation. We consider the NP-hard in the strong sense problem of combinatorial optimization by the criterion of the total weighted tardiness minimization that is included to the mathematics of the fourth level of the four-level planning (including operational) and decision making model. Based on the study of the properties of the previously developed PSC-algorithm for the problem solution and the complexity of its individual procedures, a new heuristic algorithm is created that allows real-world practical problems solution. Its effectiveness has been studied.

Key words: weighted tardiness, one machine, PSC-algorithm, heuristic.

The problem statement. Given a set of independent tasks $J = \{j_1, j_2, ..., j_n\}$, each consists of one operation. For each job j, an execution time $l_j > 0$, a weight coefficient $\omega_j > 0$ and a due date $d_j \geq 0$ are known. Tasks come to the system at the same time $r_j = 0$, $j = \overline{1,n}$. Interruptions are not allowed. The problem is to build a schedule for one machine that minimizes the total weighted tardiness of tasks:

$$f = \sum_{j=1}^{n} \omega_j \max\left(0, C_j - d_j\right), \tag{1}$$

where: C_j is the completion moment of task j.

This problem is included to the mathematics of the fourth level of the four-level planning (including operational) and decision making model [1] where operational adjustments are done of the production plan built at the third level of the model in the case of failures during its implementation.

In [2], the PSC-algorithm of the given problem solution is presented that includes the polynomial component and the exact exponential subalgorithm. The PSC-algorithm constructs an optimal schedule for the problems with up to 1000 tasks. But practical problems may include tens of thousands of tasks. Thus, the creation of heuristic algorithms for solving problems of practical dimension remains important.

Let us consider the properties of the previously developed PSC-algorithm. The PSC-algorithm consists of a series of similar iterations. At each iteration it tries to use the time reserves ($d_j - C_j > 0$) of the preceding tasks by the next competing tardy task in the sequence σ^{fp} (σ^{fp} is a sequence ordered by the priorities of the jobs ω_j/l_j in which permutations of the non-tardy tasks to later positions are done in the case if there are tardy tasks at the permutation interval) and the optimal schedule is constructed for the tasks of the current subsequence. At each iteration, the value of the functional decreases or remains unchanged, which makes it possible to build approximate or heuristic algorithms based on the PSC-algorithm. As a result of the iterations of optimization, the optimal sequence is constructed on the entire set of tasks. The PSC-algorithm includes the following basic procedures:

1. The permutation interval definition for the next tardy task of the current sequence (position p at which the job tardiness will be minimal).

2. Analysis of reserves at interval $\overline{1, p-1}$ for the current tardy task (the permutation interval extension).

3. Step-by-step optimization (reducing the tardiness of the next job) using the existing reserves on the extended permutation interval.

4. The tardy tasks optimization using the reserves released by tasks that previously used them (marked tasks) by rearranging them to later positions.

Procedure 4 is executed in the case if in result of procedure 3 the task remains tardy. Procedure 4 includes a recursive call to procedures 1 to 4 for a subsequence of tasks at the permutation interval of the marked job. In this case, in turn for the marked task, another marked task is searched for that can be put after it, which would lead to a decrease in the functional value. In this case, a combinatorial search of the marked tasks is done with subsequent optimization of the subsequence, which may be connected with the exponential complexity. Procedures 1 to 3 have polynomial complexity.

Heuristically justified modifications of procedure 4 have been developed that allow to perform a shortened directional search of the marked tasks leading to the most effective solution in the terms of functional value.

A complex search of the cases of using reserves by competing tasks may also arise if for a subsequence K of competing jobs the following is true:

$$\forall i<g,\ j_{[i]}, j_{[g]} \in K,\ l_{j_{[i]}} - l_{j_{[g]}} \le \Delta_1,\ d_{j_{[i]}} - d_{j_{[g]}} \ge \Delta_2,\ \frac{\omega_{j_{[i]}}}{l_{j_{[i]}}} - \frac{\omega_{j_{[g]}}}{l_{j_{[g]}}} \ge \Delta_3, \qquad (2)$$

where: Δ_1, Δ_2, Δ_3 are a small values, and the reserves are such that iterations of optimization are done for each competing job.

If condition (2) is satisfied for a subsequence K of competing jobs of the sequence σ^{fp}, a polynomial restriction is set on the number of executed operations to optimize a given subset of tasks, the functional value is determined at the last completed iteration, and then we skip to a competing task following the subsequence K. This heuristic is effective because when the condition (2) is satisfied, the functional value decreases insignificantly at each iteration. Thus, a significant reduction in the number of iterations can be achieved.

Statistical studies of the developed heuristic algorithm showed its high efficiency. The deviation of the functional value of the schedules obtained by the heuristic algorithm is in the range of 8 to 10% from the values obtained by the exact PSC-algorithm.

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CONTROL OF MOVING OBJECTS IN CONDITION OF CONFLICT

Annotation. The paper deals with the game problem of approaching the cylindrical terminal set by a trajectory of the quasilinear system. Concepts of upper and lower resolving functions are introduced, defined in the form of selections of special set-valued mapping. On their basis sufficient conditions for solvability of the problem are derived.

Key words: conflict-controlled process, set-valued mapping, Pontryagin's condition, resolving function, Aumann integral.

The paper concerns quasilinear conflict-controlled processes which are exposed to simultaneous action of continuous and impulse control of two counteracting sides. The moments of impulse effect as well as their magnitudes (the latter belonging to given compacts) are either fixed or chosen by the players. There are different forms of impulse impact on the dynamic system, in their number the impact brought about by the delta function in the right-hand side (it generates discontinuous trajectories). The terminal set is supposed to be cylindrical. The game is analyzed standing on the side of the pursuer who strives to steer a process trajectory to the terminal set. Sufficient conditions are developed, providing realization of the pursuer goal in some guaranteed time under any counteraction of the second player. In constructing his control the pursuer employs control prehistory of the second player or current instantaneous values of his control. The method of resolving function is used here as basic tool for investigation. The scheme of the method assumes Pontryagin's condition or some of its modifications to hold. On its basis special set-valued mappings and their support functions called the resolving functions are built. Current control of the second player known, the resolving function features control quality of the first player. In view of accumulative character of evaluation of the game scheme quality, one can describe the first direct method in terms of infinity as corresponding value of the resolving function [1, 2, 3]. Also functional form of the first direct method is given by the way of introduction of special set-valued mappings and corresponding resolving functions. Comparison of the guaranteed times of the game termination is made for the above mentioned methods. The property for joint $L \times B$-measurability of set-valued mappings and their selections super positional measurability make feasible choosing measurable control of the first player analogously to the Filippov-Castaing theorem. Corresponding condition for advantage concerning impact of impulse control is also given. The cases of only continuous or only impulse control of each player of the players are analyzed separately as well as the case of both players impulse controls. The gist of the method is construction of the resolving function appearing as the inverse Minkowski functional of certain set-valued mapping. The latter makes it possible to construct the resolving functions in analytic form for a wide class of conflict-controlled processes. Suggested scheme allows evaluation of the quality of continuous and discrete controls, in their number by the way of selection of non-convergent numerical sequence of impulse moments.

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ONE METHOD OF CONTROL IN DIFFERENTIAL GAMES WITH IMPULSE CONTROLS

Annotation. The principle of time stretching is extended to the case of impulse controls in linear differential games. Sufficient conditions for finite-time termination of the approach game are obtained. The developed technique is exemplified with the detailed study of a model game of pursuit.

Key words: principle of time stretching, pursuer, evader, Pontryagin's condition, impulse control, terminal set.

The paper concerns the linear game problem of approach in the case when a terminal set has cylindrical form and the players apply impulse controls. The problem is complicated with the fact that Pontryagin's condition, reflecting an advantage of the pursuer over the evader in control recourses, does not hold. Generalization of Pontryagin's first direct method is proposed based on using special integer-valued function – the function of time extension. Using this method sufficient conditions for bringing game trajectory to the terminal set in a finite number of control jumps are derived. In so doing, at each step control of the pursuer is built on the basis of several controls of the evader in a past as if information on current control of the evader is available with variable delay of information. Due to the developed technique it becomes possible to study in detail the game of pursuit with the mathematical pendulum dynamics of players.

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ON LINEAR OPERATOR EQUATION SOLVABILITY AND CONTROL PROBLEMS

Annotation. Necessary conditions for general linear operator equation solvability and solution presentation are proved. This allows to approach control problems directly. Criterion for adjoint operator existence and its properties are proved.

Key words: linear operator, equation solution, completion, adjoint operator, weakly continuous operator.

Adjoint operator notion is a key tool for linear functional and differential equations solving, for target functional extremum search. For linear operator of general form adjoint operator existence criterion and its major properties are proved. Then necessary conditions of general linear operator equation solvability are derived (done in [1]). This allows to find operator equation solution as functional of influence and to apply it to control problems.

N and C denote sets of all natural and complex numbers correspondingly. Everywhere below functions and functionals are complex-valued. Let L and L_1 be linear spaces over C, $\vec{0}_1$ – zero element of space L_1. $Ker\,\varphi=\{x\in L:\varphi(x)=0\}$ is *kernel of functional* $\varphi: L\to C$. $Ker\,A=\{x\in L: Ax=\vec{0}_1\}$ is *kernel of operator* $A: L\to L_1$, $Im A=\{Ax: x\in L\}$ – *image of* A. $L_0\subset L$ is a *lineal in* L if $\alpha_1x_1+\alpha_2x_2\in L_0$, $\alpha_1,\alpha_2\in C$, $x_1,x_2\in L_0$. For lineal L_0 *dimension* $\dim L_0$ (finite or infinite) is the number of elements of maximal linearly independent set in L_0. For set $S\subset L$ *linear span* $\mathscr{L}(S)$ is the minimal lineal that contains S. *Indicator function of set* H $I_H(x)$ equals 1 for $x\in H$, 0 for $x\notin H$.

Let L be a linear normed space. *Closure of set* S *in* L is denoted $\overline{(S)_L}$. Set $S\subset L$ is *dense in* L if $\overline{(S)_L}=L$. L is *separable* if there exists not more than countable set $S\subset L$ that is dense in L. Closed lineal in L is called *subspace*. *Basis in* L is a linearly independent set $S\subset L$ such that $\overline{(\mathscr{L}(S))_L}=L$. Linear space E is called *canonical* if *scalar product* $(\cdot,\cdot): E\times E\to C$ is defined with properties: 1) $(x,x)\ge 0$, and $(x,x)=0 \Leftrightarrow x=\vec{0}$; 2) $\overline{(x,y)}=(y,x)$, $x,y\in E$; 3) $(\alpha_1x_1+\alpha_2x_2,y)=\alpha_1(x_1,y)+\alpha_2(x_2,y)$, $\alpha_1,\alpha_2\in C$, $x_1,x_2,y\in E$. $\vec{0}$ denotes zero element of space E; upper line over number stands for complex conjugation. *Norm of vector in* E $\|x\|=\sqrt{(x,x)}$, $x\in E$. $S_1+S_2=\{x_1+x_2: x_1\in S_1, x_2\in S_2\}$ – *linear sum of sets* $S_1,S_2\subset E$. S_1+S_2 is called *direct sum of sets* S_1 *and* S_2 (denoted $S_1\oplus S_2$) if every decomposition $x=x_1+x_2$, $x_1\in S_1$, $x_2\in S_2$ is unique. S_1 and S_2 are *orthogonal* (denoted $S_1\perp S_2$) if $(x_1,x_2)=0$, $x_1\in S_1$, $x_2\in S_2$. For set $S\subset E$ *orthogonal complement* $(S)_E^{\perp}=\{x\in E: x\perp S\}$. $x\perp S$ will mean $\{x\}\perp S$.

Lemma 1. Let E – canonical space. Then its completion $\hat{E}$ exists that satisfies requirements: 1) E – lineal in complete space $\hat{E}$; 2) $\overline{(E)_{\hat{E}}}=\hat{E}$; 3) $\hat{E}$ – canonical space.

Theorem 1. Let E – separable canonical space. Linear functional $\varphi: E\to C$ is continuous if and only if there exists an element $a\in\hat{E}$ such that $\varphi(x)=(x,a)$, $x\in E$, and such a is unique.

Let X – complete canonical space, D_1, D_2 – lineals in X, were D_1 is dense in X. Let us call $A^*: D_2\to X$ *adjoint operator* for linear operator $A: D_1\to X$ if $(Ax,y)=(x,A^*y)$, $x\in D_1$, $y\in D_2$. Operator $A: D_1\to X$ will be called *weakly continuous with respect to* D_2 if the functional

$\varphi_y(x)=(Ax,y)$, $x \in D_1$ is continuous for every $y \in D_2$. Operator $A: E \to \hat{E}$ is called *weakly continuous* if the functional $\varphi_y(x)=(Ax,y)$, $x \in E$ is continuous for every $y \in E$.

Theorem 2. Let X – complete separable canonical space, D_1, D_2 – lineals in X, D_1 is dense in X, $A: D_1 \to X$ – linear operator. Then existence of $A^*: D_2 \to X$ – adjoint operator for A – is equivalent to each of the following statement

1. $A: D_1 \to X$ is weakly continuous with respect to D_2.
2. $Ker\,(A\cdot, y)$ is closed in D_1 for every $y \in D_2$.
3. $\overline{(Ker\,(A\cdot, y))_{D_1}} \neq D_1$ for every $y \in D_2$, except the cases when $(A\cdot, y) \equiv 0$.

Theorem 3. Let X – complete separable canonical space, D_1, D_2 – lineals in X, D_1 is dense in X, $A: D_1 \to X$ – linear operator and its adjoint operator $A^*: D_2 \to X$ exists. Then the following statements are true.

1. A^* is unique. 2. A^* is linear. 3. A^* is weakly continuous with respect to D_1. 4. $Ker\,A$ is closed in D_1.5. $Ker\,A^*$ is closed in D_2.

Additionally let D_2 be dense in X. Then the following statements are true.

6. $(A^*)^* = A$.7. $\overline{(Ker\,A)_X} \perp \overline{(Im\,A^*)_X}$, and $X \supset \overline{(Ker\,A)_X} \oplus \overline{(Im\,A^*)_X}$. 8. If $Ker\,A$ is dense in $(Im\,A^*)_X^{\perp}$ then $X = \overline{(Ker\,A)_X} \oplus \overline{(Im\,A^*)_X}$.

Consider equation $Ax = f$ with linear operator $A: E \to \hat{E}$. We can interpret it as description of a linear system change according to influence $f \in \hat{E}$, part of which may be natural force, another part – control element.

Theorem 4. Let E – separable canonical space, $A: E \to \hat{E}$ – linear weakly continuous operator, $f \in \hat{E}$ and equation $Ax = f$ has a solution $x \in E$. Then the following statements are true.

1. Solution $x \in E$ is unique $\Leftrightarrow$ $Ker\,A = \{\vec{0}\}$. 2. $f \perp Ker\,A^*$.

Additionally let $k_0 = \dim E$; $\{b_k, k = \overline{1,k_0}\}$ – a basis in E; $E^{(2)} = \overline{(\mathscr{L}(\{A^* b_k\}))_{\hat{E}}}$; $E^{(1)} = (E^{(2)})_{\hat{E}}^{\perp}$; $k_1 = \dim E^{(1)}$; $\{d_k, k = \overline{1,k_1}\}$ – an orthonormal basis in $E^{(1)}$; elements $g_k = A^* b_k$, $k = \overline{1,k_0}$ are orthogonalized by the rule $e_1 = \| g_1 \|^{-1} g_1$, $e_k = \left\| g_k - \sum_{l=1}^{k-1} (g_k, e_l) e_l \right\|^{-1} \left(g_k - \sum_{l=1}^{k-1} (g_k, e_l) e_l \right)$, $k = \overline{2,k_2}$ with $k_2 \in N \cup \{\infty\}$ (if for $k \in N$ $g_k - \sum_{l=1}^{k-1} (g_k, e_l) e_l = \vec{0}$ then g_k is declined and orthogonalization is continued starting with g_{k+1}). Then the following statements are true.

3. $\{d_k\} \cup \{e_k\}$ is orthonormal basis in $\hat{E}$. 4. $x = \sum_{k=1}^{k_1} (x, d_k) d_k + \sum_{k=1}^{k_2} (x, e_k) e_k$. 5. If the result of orthogonalization $\{g_k\}$ is presented as $e_k = \sum_{l=1}^{k} \gamma_{kl} g_l$, $k = \overline{1,k_2}$, where $\gamma_{kl} \in C$, $l = \overline{1,k}$, $k = \overline{1,k_2}$, then $(x, e_k) = \sum_{l=1}^{k} \overline{\gamma_{kl}} (f, b_l)$, $k = \overline{1,k_2}$. 6. For any $\{f_n\} \subset Im\,A$ such that $(f_n, b_l) \to (f, b_l)$, $n \to \infty$ for every $l \in N$ and for any $\{x_n\} \subset E$ such that $Ax_n = f_n$, $n \in N$ convergence $(x_n, e_k) \to (x, e_k)$, $n \to \infty$ holds for every $k = \overline{1,k_2}$.

Coordinate-wise convergence in Theorem 5 allows to build solution approximations basing on influence function f and basis $\{b_k\}$. It is particularly effective in case of finite-dimensional equations as well as of finite-dimensional approximations for general functional-differential equations.

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UDK 519.8

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SYSTEM APPROACH TO MODELING AND OPTIMIZATION OF NATURAL GAS DISTRIBUTION AND STORAGE

Annotation. The efficient algorithms for nonlinear programming problems for calculating networks have been offered, as well as the new network models to determine the optimal flows taking into account consumer demand, productivity variable sources and availability of temporary storage of natural gas.

Key words: optimization models, flow distribution problems, gas networks, nonlinear programming methods.

One of the main aspects of system research in the energy sector, in particular in the gas industry, is mathematical modeling and optimal management of complex energy systems. The main strategic directions for increasing the reliability and efficiency of natural gas transportation, storage and distribution managing are control strategies based on adequate mathematical models, effective methods and modern information support.

The aim of the work is to construct optimization models for the flows distribution, as well as to create effective non-linear programming algorithms for network problems. To solve these problems, a series of models describing the transportation and distribution of resources between consumers, taking into account the accumulation of stocks in certain temporary storage tanks, was developed.

The gas transposition scheme includes the extraction of gas in gas fields, which have limitations on production volumes; pumping gas through compressor stations, each of which in turn has limited capacity and transporting it through various sections of pipelines with limited capacity. Reliability of transit gas supplies and security of gas supply to domestic consumers is largely ensured by a complex of underground gas storage facilities [1]. The whole complex of gas production, distribution and transportation should be considered as a single system and it is necessary to solve the task of managing gas transmission networks from the point of view of a system approach [2].

A series of models of resource distribution problems that took into account customer orders, variable source productivity and the availability of temporary product stores were analyzed and numerically tested [3].

The problems with nonlinear objective functions of general form and network structure of constraints, which allow to reach quite a wide range of networks using common approach, were considered. Programming methods and algorithms were proposed for finding optimal flows distribution.

For calculations the modifications of well-known methods of nonlinear programming were applied. The proposed methods of the first order is comparable by convergence rate with the methods of sequential quadratic programming through an efficient algorithm for the solution of the auxiliary quadratic problems and convenient procedure of step factor calculation.

The constructed models and algorithms for optimization of flow distribution allow to create effective information-analytical systems for optimum control of the network distribution systems.

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INVARIANT RELATIONS IN THE THEORY OF REDUNDANCY CONTROLLED DYNAMIC SYSTEMS

Annotation. The relations between the control functions of dynamical systems that do not depend on the subjective aspects of the optimization problem: boundary conditions and the quality criterion – are considered. Such connections take place for systems in which the dimension of the set of admissible controls is not less than the number of equations of motion into which the control functions directly enter. It is shown that these relations express the principle of minimum energy dissipation of control. The possibility of using this principle as a criterion for selecting actual motions from a set of virtual motions in the mathematical description of control processes in technical devices and in wildlife is discussed.

Key words: redundancy of controls, invariance, hierarchy, dissipation of control energy, expediently controlled dynamic system, selection criterion.

In solving some problems of optimizing the motion of objects described by ordinary differential equations relations between control functions that do not depend on the boundary conditions of the problem and the criterion for the quality of control had been obtained. The nature of such unusual relationships is not discussed in publications that are known to the authors of the report. The purpose of the report is to determine the conditions under which such relationships take place, to clarify and discuss the theoretical and applied aspects of the organization of control process, due to the need for their realization.

Formulation of the problem

Controlled objects are considered, the equations of functioning of which are written in the form:

$$\frac{dx_i}{dt} = f_i(x,u) \qquad i=1,...,n, \qquad \frac{dx_j}{dt} = f_j(x), \qquad j=n+1,...,m \tag{1}$$

here $x=\{x_1,...x_m\}$ – phase vector of the system, $u=\{u_1,...,u_r\}$ – control vector, t – time. For $r \geq n$, the described system (1) is called a system with redundant control. Let the Mayer problem be formulated to transfer an object from some initial position $x(t_0)$ in the phase space to the indicated final position $x(t_1)$ with a minimum value of the functional $J(u)=\varphi(x(t_1))$ In the analysis of optimal control using the maximum principle, it is clarified that for $r \geq n$ the satisfaction of the necessary optimality conditions is possible if the following ($r-n+1$) relations are satisfied,

$$\frac{D(f_1,..., f_n)}{D(u_1,...,u_{n-1},u_n)}=0, \qquad \frac{D(f_1,..., f_n)}{D(u_1,...,u_{n-1},u_n)}=0, \qquad \frac{D(f_1,..., f_n)}{D(u_1,...,u_{n-1},u_r)}=0 \tag{2}$$

which are the rules of coordination of redundant controls. A distinctive feature of the relations (2) is their independence from the conjugate functions of the problem and, consequently, from the boundary conditions of the Mayer problem and the control quality criterion. Note that relations (2) *can be written out for the system* (1) *even before the formulation of any Mayer optimization problem.* It is necessary to find out which property of the object these relations, which are invariant with respect to the goal and the control price, are expressed.

Interpretation of relations (2) is obtained by analysing them in the space of the hodograph of phase velocity. It turned out that all vectors of phase velocity variations $\partial f/\partial u_1, \partial f/\partial u_2, ..., \partial f/\partial u_r$

under optimal control must be collinear with a single $(n-1)$-dimensional hyperplane Ψ. Consequently, on the optimal trajectories of system (1) the functional

$$\Omega = \frac{1}{2}\int_{t_0}^{t_1}(n_1^2 + n_2^2 + ... + n_r^2)\Delta u^2 \cdot dt \qquad (3)$$

takes the minimum value of zero. In the formula (3) n_k is the projection of the vector $\partial f / \partial u_k$ onto the normal to the hyperplane Ψ. The nonzero value of the functional (3) characterizes the energy loss of control when selecting the control actions, which is performed without taking into account the coordination rules (2). Thus, satisfaction of the relations (2) ensures minimization of these losses, i.e. implementation of the principle of minimum control energy dissipation. In this case, $(r-n+1)$ constraints (2) imposed on the choice of r control functions. The dimension r of the set of admissible controls that is postulated in the formulation of the problem reduces to the dimensionality $(n-1)$ of the set of optimal controls.

We call a system of differential equations (1) supplemented by finite relations (2), expediently controlled system. In order to solve the optimization problem, it is necessary to select only $(n-1)$ controls taking into account the boundary conditions and the functional. The remaining controls are calculated according to the rules (2). Invariance of these relations allows to "build" them into the control system of the object, which should, at least, have two levels of hierarchy. The task of the top level is to evaluate the state of the object and in the choice of controls based on the selected target and understanding of control prices. At the lower level, "internal" controls are generated. The use of the proposed structure of the control system makes it possible to reduce the dimensionality of the search space for controls of technical objects movement.

The problem of diminishing dimensionality is especially relevant in describing management processes in living nature, since redundancy is one of the main attributes of living matter and one of the key problems of an adequate description of its functioning. Thus, the creator of the modern theory of functional systems, P. K. Anokhin in his work "Fundamental Questions of the General Theory of Functional Systems" (1971) concretely formulates the main task: "... we must discover those determinants that release the components of the system from excess degrees of freedom. ... Without the definition of this factor, no single concept of system theory can be fruitful. " P. K. Anokhin proposes to consider the concrete result of the system's activity as such a system-forming factor.

This hypothesis of P. K. Anokhin, supplemented by the assumption of the optimality of control processes in living nature, makes it possible to use the theory of optimization as one of the tools in the formalized description of these processes. The above principle is proposed to be used as a hypothetical form of the general experimental principle of minimum energy dissipation, specific for wildlife. The possibility of using this principle as a criterion for selecting actual motions from a set of virtual motions in the mathematical description of control processes in technical devices and in wildlife is discussed.

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USE OF STATISTICAL ANALYSIS FOR IDENTIFICATION OF THE MATHEMATICAL MODEL OF SOLVING APPLIED PROBLEMS WITH THE PURPOSE OF COSTS OPTIMIZATION

Annotation. The method of statistical analysis has been provided, considered the notion of identification, the influence coefficients of model parameters on determined values of maneuvering and economic characteristics of the vessel were calculated,

Key words: statistical analysis, probability, mathematical model, optimization.

Formulation of the problem

The development of statistical methods in the economics very often requires obtaining objective information for choosing the method of forecasting the situation. It is possible to demonstrate the advantages of using some probabilistic approaches in a practical example of navigation in the implementation of maneuver.

Essence of research

There is a lot of applied problems in the life of society in which it is difficult or impossible to calculate many indicators without the use of modeling. The maintenance of river and sea vessels and ports is an urgent task, for solving which it is necessary to apply the scientific method of mathematical statistics. Considering the statistics of the accident rate, it becomes clear that the life cycle of the equipment has certain time and space limitations. The multidimensionality of the economic and technical indicators of each operating unit complicates the intuitive assessment of the situation in each specific case. It is unprofitable to conduct many tests and the parameters of the characteristics come with distortions. It becomes clear that the application of multidimensional statistical analysis in these conditions allows us to take into account all the difficulties listed above. It is proposed to carry out statistical processing of a large number of observations arriving in time, taking into account probabilistic errors within the limits of the allowed limitations. To more accurately identify the proposed mathematical-statistical model, it is necessary to collect all the information arriving at different moments in the ship's life cycles and record it in the corresponding matrix. This information must be taken into account continuously during the operation of the vessel and used in the updated model to predict the planned maneuvers.

When creating mathematical (or simulation) models of complex technical, economic, information and other systems, it is very often possible to manage (forecast) the behavior of the system by affecting on its main, "node" indicators. Since in practice the input data is submitted with distortions of a probabilistic nature, it is necessary to study the evaluation of the behavior of some functions from such "node" characteristics, but already in the following construction:

Let $X_i, i=\overline{1,s}$ – independent observations over a random matrix $\mathrm{A}+\Xi$, where $\mathrm{A}=(a_{ij})$ is real matrix, $i=\overline{1,n}, j=\overline{1,m};$ $\Xi=(\xi_{ij})$ – random matrix of the same dimension.

We denote by λ_k the singular eigenvalues of the matrix A, and by $\hat{\lambda}_k$ the singular eigenvalues of the matrix $\mathrm{A} = s^{-1} \cdot \sum_{i=1}^{s} X_i$. Obviously, if the elements of the matrix Ξ are independent and have zero mean and dispersions $s^{-1}\sigma^2$, then the elements of the matrix A are also independent and have dispersions $s^{-2}\sigma^2$.

We assume that the numbers m, n, s, σ^2 are dependent and satisfy the following conditions:

$$\overline{\lim_{m\to\infty}} \sigma^2 s^{-1} n < \infty, \quad \overline{\lim_{m\to\infty}} \sigma^2 s^{-1} m < \infty, \quad \overline{\lim_{m\to\infty}} mn^{-1} < 1, \quad \underline{\lim_{m\to\infty}} mn^{-1} > 0. \qquad (1)$$

Let

$$\lambda_k(\mathrm{A}) \le C < \infty, \; C = const, \; k = 1, 2, \ldots, \quad \lambda_1 \ge \lambda_2 \ge \ldots \ge \lambda_m . \qquad (2)$$

The expression $(-\mathrm{Iz} + \widehat{\mathrm{A}}^T \widehat{\mathrm{A}})^{-1}$ is called the resolvent of the matrix $\widehat{\mathrm{A}}^T \widehat{\mathrm{A}}$, which is the Gram matrix. The following theorem is proved for it.

Theorem. Let conditions (1), (2) be satisfied, and also let the random elements ξ_{ij} of the matrix Ξ are independent for each n, $\mathrm{M}\xi_{ij} = 0$, $\mathrm{D}\xi_{ij} = s^{-1}\sigma^2$. Then

$$\mathrm{p}\lim_{m\to\infty} m^{-1} s \, \mathrm{P}\left[(-\mathrm{Iz} + \widehat{\mathrm{A}}^T \widehat{\mathrm{A}})^{-1} - \mathrm{M}(-\mathrm{Iz} + \widehat{\mathrm{A}}^T \widehat{\mathrm{A}})^{-1} \right] = 0 .$$

The proof of this theorem is based on the standard perturbation formulas for the resolvents of matrices [1].

Conclusions. Observations $X_1, X_2, \ldots, X_s$ were made on a particular class of vessels. These observations reflected the measurements of the characteristics of each vessel: the thrust of the propeller to the force of resistance to movement, the strength of the longitudinal resistance, the drift angle, the acceleration, the braking characteristics of the ship, the wind speed, the direction of the ship's wind drift, parameters of movement, etc. A lot of such data is collected. Carrying out calculations, determine which coefficients are more influential on a certain characteristic and in which direction. The obtained coefficients of influence make it possible to provide the identification process of the constructed model. And this in turn will allow not only to reduce material costs, but also to optimize the qualitative forecast of the researched processes.

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NONLINEAR DISCRETE MODELS IDENTIFICATION METHOD FOR GEOMAGNETIC INDECES PREDICTION

Annotation. The report deals with identification of nonlinear discrete models for geomagnetic indices prediction. The method is based on maximizing the uncertainty measure (Shannon's entropy) of distances (norms) in a multidimensional phase space. Euclidean norm and Gram-Schmidt reorthonormalization is used. The distribution of distances (norms) is considered. The method is intended for identification with the corresponding the Lyapunov spectrum.

Key words: identification method, distribution, Shannon's entropy, Lyapunov exponents.

Decreasing the magnetic field force (MFF) for last century by 10% and increasing the "South Atlantic anomaly" where MFF has decreased by almost a third and likely a geomagnetic reversal makes the topic very important for research. Therefore, among the many problems of space weather an important role takes geomagnetic indices prediction, such as DST and Kp indices [1, 2]. Artificial neural network, regression models, NARMAX, and bilinear models is most applicable for solving the prediction problem. For parametric identification of these models are used mainly least-squares method or maximal likelihood method, and others. However, identification with appropriate the Lyapunov exponents spectrum needs further research. This report is dedicated to the developed nonlinear discrete models identification method with appropriate the Lyapunov exponents spectrum for geomagnetic indices prediction. The developed method is based on maximizing the uncertainty measure (for example, Shannon's entropy) of distances (norms) in a multidimensional phase space. Gram-Schmidt reorthonormalization is used with applying maximal entropy principle. The main advantage of this method is identification with the corresponding the Lyapunov spectrum and their decomposition [2]. By the presented principle in [2] for developed method the functional with the Euclidean norm $d = \|w\| = \left(w_1^2 + w_2^2 + \ldots + w_m^2\right)^{1/2}$ is given by:

$$H = -\sum_{i=1}^{m}\sum_{j=1}^{n} f(d_i^j)\ln f(d_i^j) \to \max\,, \tag{1}$$

$$f(d_i^j) = \frac{1}{a\sqrt{2\pi}}\left[\exp\left(-\frac{\left(d_i^j-\mu\right)^2}{2a^2}\right) + \exp\left(-\frac{\left(d_i^j+\mu\right)^2}{2a^2}\right)\right], \tag{2}$$

where: a – parameter scale distribution (a >0), m – dimension of phase space, n – cardinal number of time series, $f(d_i^j)$ – density distribution of distances (norms) d_i^j, H – Shannon's entropy, μ – position parameter.

The functional of the developed identification method for the discrete case have presented by using Shannon’s entropy. The method is intended for identification with the corresponding the Lyapunov spectrum.

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INVENTORY CONTROL OF A MANUFACTURING SYSTEM WITH UNCERTAINTY BASED ON ADAPTIVE APPROACH

Annotation. The paper deals with controlling the in-process inventories for the manufacturing system of a typical machine-building enterprise. The decision-making is implemented under uncertainty associated with the absence of exact machining model. To cope with this uncertainty, the adaptive control approach is proposed. Within this approach, a new adaptive reorder policy is developed.

Key words: adaptation, estimation algorithms, identification, inventory control, uncertainty.

The in-process inventory control problem stated several decades ago remains a topic of considerable and widespread interest up to now. To implement a perfect inventory control for a manufacturing system, the exact mathematical model with respect to the machining is required. In practice, however, there is only approximate model of the machining that may be used in the decision-making system. Moreover, machine failures are possible, in principle. Due to these facts, there is some uncertainty when the order (reorder) policy is formed.

The system for controlling the so-called in-process inventory of a typical machine-building enterprise whose production line includes the machining, the transport, the storage and the assembly line is considered. It operates as follows. At the start $t = t_n := nT_0$ of each *n*th scheduled time interval $[t_n, t_{n+1}]$ $(n = 0, 1, 2, \ldots)$ having the same duration $T_0 = t_{n+1} - t_n,$ the decision-making system sends the request about the current product stock level $H(t)$ equal to $H(t_n) := H_n.$ After receiving this information, the deviation $e_n := r^0 - H_n$ of H_n from the required level of safety stock value, $r^0,$ is determined. Next, it places the order (reorder), $\theta_n,$ defining the product volume to be produce during the planning interval $t_n \le t \le t_{n+1}$ according to the following rule: $\theta_n = \theta_{\max}$ if $\theta_n^{\rm c} > \theta_{\max},$ $\theta_n = \theta_n^{\rm c}$ if $0 \le \theta_n^{\rm c} \le \theta_{\max}$ and $\theta_n = 0$ if $\theta_n^{\rm c} < 0.$ Here $\theta_{\max}$ denotes maximum order size which might be produced at $t \in [t_n, t_{n+1}]$ by introducing all available manufacturing capacity, and $\theta_n^{\rm c}$ is defined by a given order policy to be specified later.

Based on the value of $\theta_n,$ the decision-making system determines the production capacity q_n necessary to produce the order quantity $\theta_n.$ This capacity may be expressed as

$$q_n = q(\theta_n) \qquad (1)$$

with some vector-valued operator $q.$ Equation (1) describes an operation schedule for each machine.

The product fabricated by machining to the end of time interval $[t_n, t_{n+1}]$ is

$$Q_{n+1} = P_{n,\,n+1}(q_n) - \xi_{n,\,n+1}, \qquad (2)$$

where $P_{n,\,n+1}$ represents, in general, the time-varying operator. $\xi_{n,\,n+1}$ is an irregular bounded variable which may be understood as a non-negative noise $(\xi_{n,\,n+1} \ge 0)$ caused by the machine failure.

It is assumed that all the product whose quantity Q_{n+1} is delivered through the intermediate transport to the storage at the time instant $t = t_{n+1} + \tau$ with some time delay $\tau < T_0$. The inventory level H_{n+2} at the time instant $t = (n+2)T_0$ will then be given as

$$H_{n+2} = H_{n-1} - \nabla\tilde{Q}_{n+1,\,n+2} + Q_{n+1},$$

in which $\nabla\tilde{Q}_{n+1,\,n+2}$ is the lot size taken on the demand of the assembly line from storage bunker during the period $t_{n+1} \le t \le t_{n+2}$.

From (2) together with (1) it follows that

$$Q_{n+1} = P_{n,\,n+1}(q_n(\theta_n)) - \xi_{n,\,n+1} \qquad (3)$$

leading, in actual case, to $Q_{n+1} \ne \theta_n$ even when $\xi_{n,\,n+1} = 0$ because of the absence of the exact machining model. Defining the time-varying $\gamma_n = P_{n,n+1}(q_n(\theta_n))/\theta_n \le 1$ rewrite (3) as

$$Q_{n+1} = \gamma_n\theta_n - \xi_{n,\,n+1}. \qquad (4)$$

Suppose that γ_n is a random coefficient which has nonstochastic nature and changes within the interval $\underline{\gamma} \le \gamma_n \le 1$ having a lower bound $\underline{\gamma}$, which remains unknown. Further, let $0 \le \xi_{n,\,n+1} \le \bar{\xi}$, where $\bar{\xi}$ representing the upper bound on $\xi_{n,\,n+1}$ is assumed to be known. Then (4) yields

$$Q_{n+1} = \gamma\theta_n - \bar{\xi}/2 + v_{n,n+1}, \qquad (5)$$

where γ is a unknown constant and $v_{n,n+1}$ denotes an equivalent "symmetrical" noise satisfying $|v_{n,n+1}| \le \varepsilon$ in which $\varepsilon \le [(1-\underline{\gamma})\theta_{\max} + \bar{\xi}]/2$. Since $\underline{\gamma}$ is unknown, the upper bound on ε is unknown.

Introduce the control performance index

$$J = \lim_{n\to\infty} \sup |e_n|.$$

Then, the control aim is to form the reorder policy which yields $\{\theta_n\} := \theta_0, \theta_1, \theta_2, \ldots$ minimizing J in accordance with

$$J \to \min_{\{\theta_n\}} \qquad (6)$$

provided that there are uncertainties with respect to γ and $v_{n,n+1}$.

To solve the minimization problem (6), the adaptive reorder policy in which the variable θ_n^c is specified as

$$\theta_n^c = (e_n + \nabla\tilde{Q}[n, n+1] + \nabla\tilde{Q}[n+1, n+2] - \gamma(n)\theta_{n-1})/\gamma(n) \qquad (7)$$

is proposed. In the equation (7), $\nabla\tilde{Q}[n, n+1]$ and $\nabla\tilde{Q}[n+1, n+2]$ denote the estimates of $\nabla\tilde{Q}_{n,\,n+1}$ and $\nabla\tilde{Q}_{n+1,\,n+2}$, respectively, predicted at $t = t_n$, and $\gamma(n)$ is an estimate of unknown γ generated by a new identification algorithm. It exploits the recursive point and set-membership adaptation procedures.

The proposed algorithm guarantees that the control objective (6) will be achieved. This algorithm makes it possible to improve the decision-making system via the use of a novel reorder policy formed by this system. Contrary to [1], it does not require a priori information related to bounds on uncertainty. This feature seems to be important from a practical point of view.

The approach advanced in this paper might be extended on the case where the upper bound on the variable caused by the machine failure is unknown.

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IDENTIFICATION AND PREDICTION OF MOISTURE DISTRIBUTION IN SOIL FOR IRRIGATION CONTROL

Annotation. Receiving the correct mathematical dependencies of various dynamical process is known to be complex scientific problem. Application of neural network along with experimental and semi-empirical data helps to predict the changes of soil structure during the watering process.

Key words: irrigation, soil, humidity, mathematical model, neural network.

Soil irrigation is known to be the most efficient way to increase the plats productivity among various argotechnical methods. Retaining the correct water level for specific plant culture allows to receive the maximal crop. This task is solved by modern irrigation systems that manage different parameters from external environment and choose the necessary control impact. From the other side, the irrigation changes the wide set of soil parameters and effects on the destructive phenomena progress, such as soil erosion and salinization. The probabilistic nature of various processes complicates the general soil parameters accounting, which results in errors in water resources use and selection of irrigation standard. Thus it is important to consider not only the initial physical and chemical soil parameter, but also the general dynamic of stochastic processes of soil degradation.

Wide amount of research work is focused on analysis of structural soil changes under the external environment influence – the fractal model of soil structure is considered as well as water conduction index for specific models. The general provision of rain machines ecological reliability and assessment of irrigation erosion permissible norms are presented in [1]. An influence of soil faults and cracks on infiltration characteristic were analyzed in [2, 3]. The authors show that traditional methods for assessment of infiltration speed give the incorrect description of soil water level by omitting the soil cracks during soil humidification. Various publications are devoted to the analysis of preferential flow and it features.

The main aim of conducted research work is to analyze identification schemes of the infiltration characteristic during the irrigation and prediction of humidity distribution in the soil to properly organize irrigation process.

Let us consider the porous substance as fractal structure to construct mathematical model of the fluid flow in the porous medium. The dendritic structure with fractal dimension $D \approx 1.7$ can be obtained in the simplest case. The consideration of the probability of part adherence to the cluster – p increases the model flexibility and approximates it to the real conditions of moisture distribution with the presence of soil inhomogeneity. The minimal valuse of probability coefficient that will increase in time under the influence of adverse factors can be treated as initial model state.

Thisemerges the preferential flows appearance and violates the general moisture distribution in the soil. The graphics show that deep is increased with the reduction of moisture amount in the topsoil. The inhomogeneity of distribution characteristic effects the assessment accuracy and complicates the irrigation systems management.

The transfer function of the second-order inertial oscillating cell was used as base for description of the output moisture distribution function (Table 1). The picture 1 shows the management structural scheme. An artificial neural network (NN) was applied to identify and predict moisture distribution characteristics.

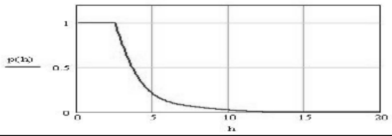
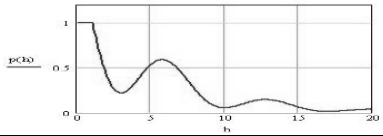
The condition of moisture distribution in the soil under the constant irrigation norm within the presented model can be shown as following equality:

$$\int_0^{h1} p_1(h)dh = \int_0^{h2} p_2(h)dh \text{ при } V = const, \quad (1)$$

where p_1 and p_2 are relative humidity with different distribution variants; h – deep, m; V – volume, m^3.

Table 1

Transfer function of inertial oscillating cell

W(p)	Standard distribution characteristic	High inhomogeneity
$W(p)=\dfrac{k}{T_1^2 p^2 + T_2 p + 1}$		

The resulting moisture distribution function is compared against the standard model and sent to the NN input. The training set for NN was received from fractal model. NN modelling and synthesis was performed in MATLAB.

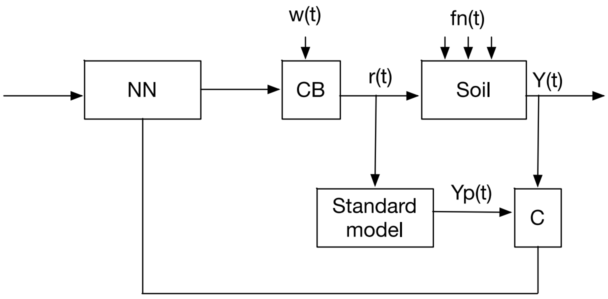


Figure 1 – Changes identification scheme in soil structure: CB – control block, C – control.

The combination of classical algorithm of back error propagation with coefficient of the learning speed adaptation along with it's modified variant with "inertia" of weight and displacement correction was applied to train NN (Fig. 2).

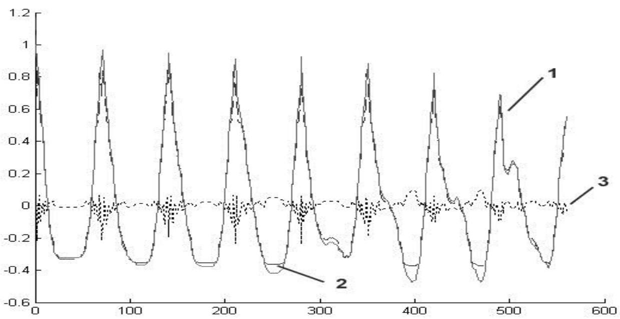


Figure 2 – Moisture distribution modelling results: 1 – correlation of moisture distribution functions; 2 – NN result; 3 – error.

Conclusions.

1. The presented application of NN and experimental semi-empirical data allows to predict changes in soil structure during hydration process. The homogeneity of moisture distribution is a basic criterion during the assessment of irrigation effectiveness.

2. The presented approach can be applied during organization of irrigation process.

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A CRITERION OF LEAST INTER-CENTERS DEVIATIONS IN PROBLEMS BI-CLUSTERING OF COMPLEX OBJECTS

Annotation. The article considers one of the quality clusterization criterion, which to some extent regularize the known incorrectness related to the nature of cluster analysis tasks in "without a teacher" statement. For the purpose of this regularization the problem is considered in the formulation of the clustering task in a broad sense or so called bi-clustering with a target feature.

Key words: cluster analysis, bi-clustering, criterion, feature, object.

In the traditional statement of the cluster analysis problem "without a teacher" have a place the known incorrectness to overcome which is necessary to apply a priori information with heuristic assumptions concerning the existing sample of projects. In this case, often arises a problem of design the specific optimality criteria in the clustering synthesis and selection informative features subspaces. In order to regularization of incorrectness we consider here the clustering problem within the statement in a broad sense or so called bi-clusterization, which often occurs in the economy, the ecology, energy, medicine, biology and in many other application areas.

STATEMENT OF THE BI- CLUSTERIZATION PROBLEM

Let we have the general array of input data in such kind:

$$\tilde{X} = \left(x_{0j} \vdots x_{ij} \in X \right),\ j = \overline{1,m}, i = \overline{1,n}\ , \tag{1}$$

where: $x_{0j} \in (x_{01}, x_{02}, ..., x_{0m})$ – vector of target features, X – matrix of input features. That is, the each object $\omega_j \in \Omega$ is described as $\omega_j = \left(x_{0j} \vdots x_{ij} \in X \right), i = \overline{1,n}$. Required:

1) to synthesize a subset of $\left\{ x_\eta^* \right\} = X^* \subset X$, $\eta = 1, ..., n^*, n^* \le n$ of the available features, the best for a given optimality criterion and that would allow:

2) to classify all objects from Ω on $k < m$, $k = 1, ..., K$ homogeneous groups.

A CRITERION OF LEAST INTER-CENTERS DEVIATIONS
IN INDUCTIVE CLUSTER ANALYSIS

It is known that among the major characteristics of the *k*-th cluster (for the convenience we will consider Euclidean space of $\mathbb{R}^N$) is its center of mass in the feature space *X*:

$$\bar{m}_k(X) = \left\{ \frac{1}{r_k} \sum_{l=1}^{r_k} x_{li},\ i = 1, ..., n \right\},\ x_i \in X\ , \tag{2}$$

Use aa target feature as regularizing element and calculate the center of the *k*-th cluster only the values of x_0 objects ω_j^k in the *k*-thcluster. Expression (2) becomes:

$$\bar{m}_k(x_0) = \hat{m}_k = \frac{1}{r_k} \sum_{l=1}^{r_k} x_{0l}\ . \tag{3}$$

As with inductive modeling [2] the input set of $\omega_j \in \Omega,\ j = \overline{1,m}$ here is also divided into two subsets of Ω^A and Ω^B such that: $\Omega^A \cup \Omega^B = \Omega,\ \Omega^A \cap \Omega^B = \varnothing$.

Suppose that on subsets of Ω^A and Ω^B one of the procedures, for example [2], has been received clusterizations of $s_t^A \in S^A$ and $s_t^B \in S^B$ with the same number of clusters $k_t^A = k_t^B = K_t$ (*t* – number of clusterization that corresponds to some subspace of features $X_t \subset X$) in Euclidean subspace of features $X_t \subset X$ and let for all K_t clusters from s_t^A and s_t^B calculated their centers $\dot{m}_k^A$ and $\dot{m}_k^B$, $k = 1,..., K_t$, along the axis x_0.

Then the optimality criterion of regularized bi-clusterization can be written in the general normalized form as:

$$\rho^2(\dot{m}) = \sum_{k=1}^{K} (\dot{m}_k^A - \dot{m}_k^B)^2 \; / \; \sum_{k=1}^{K} (\dot{m}_k^A + \dot{m}_k^B)^2 \rightarrow \min . \qquad (4)$$

Criterion (4) in the inductive cluster analysis is called as the criterion of least inter-centers deviations [3]. In this case the inter-centers deviations belong to the different subgroups and, of course, to different cluster groups or subsets. However, and this is important to emphasize that both subgroups belong to the same experiment i.e. believed that the objects were selected with statistically similar characteristics.

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THE ALGORITHM DESIGN FOR THE MAIN DRIVE SPEED CONTROL SYSTEM OF THE METAL-CUTTING TOOL

Annotation. Analytical expressions describing the developed speed control law for the machine tool main drive in the form of difference equations are obtained. The main drive speed control algorithm for the microprocessor module is developed, which generates the appropriate control pulses for the power switches of the self-commutated voltage inverter on the basis of the input information about the spindle reference speed signal, the phase currents of the induction motor stator winding and the actual mechanical spindle speed.

Key words: metal-cutting tool, speed control system algorithm.

For the experimental verification of the theoretical control system optimization research for the metal cutting machine tool main drive the power circuits of the self-commutated voltage inverter and control card that meet the requirements imposed on power circuit elements and microprocessor module. Induction motors require very complex control algorithms because there is no linear relationship between the motor currents and either the torque or the flux. This means that it is difficult to implement the speed or the torque control algorithm because of the coupling between flux and torque current components [1]. The electrical drive control system has great timing requirements. It is important for the rapid task execution cycle: reading inputs, program execution, setting outputs, communication. In order to ensure high dynamic, the drive control system algorithm should be executed in less time than inertia of controlled system [1]. Therefore the purpose is to develop an electromechanical system control algorithm and to research the quality of the optimized machine tool main drive control system performance.

The main program of the microprocessor module (Fig. 1) provides initial device initialization, all required functional block setting and recording of the control process initial conditions to the program variables. After this it goes to endless empty loop, which is interrupted for the routine processing of the control pulse forming based on the current information about controlled induction motor drive parameters and the system protection in case of the electric drive emergency state.

To use the developed control law in microcontroller programming z-transform of the speed controller transfer function is carried out

$$W_{\text{p}}(s)=\frac{u(t)}{e(t)}=\frac{k_3s^2+k_1s+k_2}{s(cs+1)}=\frac{k_3\left(\frac{1-z^{-1}}{T_s}\right)^2+k_1\left(\frac{1-z^{-1}}{T_s}\right)+k_2}{\text{c}\left(\frac{1-z^{-1}}{T_s}\right)^2+\left(\frac{1-z^{-1}}{T_s}\right)}, \quad (1)$$

where: $u(t)$ – output speed regulator signal; $e(t)$ – input error signal; T_s – sample time, s.

After expression simplifying we obtain

$$\frac{u(t)}{e(t)}=\frac{k_3z^{-2}-z^{-1}(2k_3+k_1T_s)+\left(k_3+k_1T_s+k_2T_s^2\right)}{\text{c}z^{-2}-z^{-1}(2c+T_s)+(c+T_s)}, \quad (2)$$

from which the expression for the speed controller output signal as a difference equation can be found

$$u(t)=\frac{k_3e(t-2)-e(t-1)(2k_3+k_1T_s)}{c+T_s}+\frac{e(t)\left(k_3+k_1T_s+k_2T_s^2\right)}{c+T_s}-\frac{cu(t-2)-u(t-1)(2c+T_s)}{c+T_s}. \quad (3)$$

Similarly z-transform of the PI current regulator transfer function is carried out

$$W_{\text{p}}(s)=\frac{u(t)}{e(t)}=\frac{k_Ps+k_I}{s}=\frac{k_P\left(\frac{1-z^{-1}}{T_s}\right)+k_I}{\left(\frac{1-z^{-1}}{T_s}\right)}, \quad (4)$$

where the expressions of current regulator output signals can be found as

$$u(t) = u(t-1) + k_{\text{I}} T_s e(t) + k_{\Pi}(e(t) - e(t-1)). \quad (5)$$

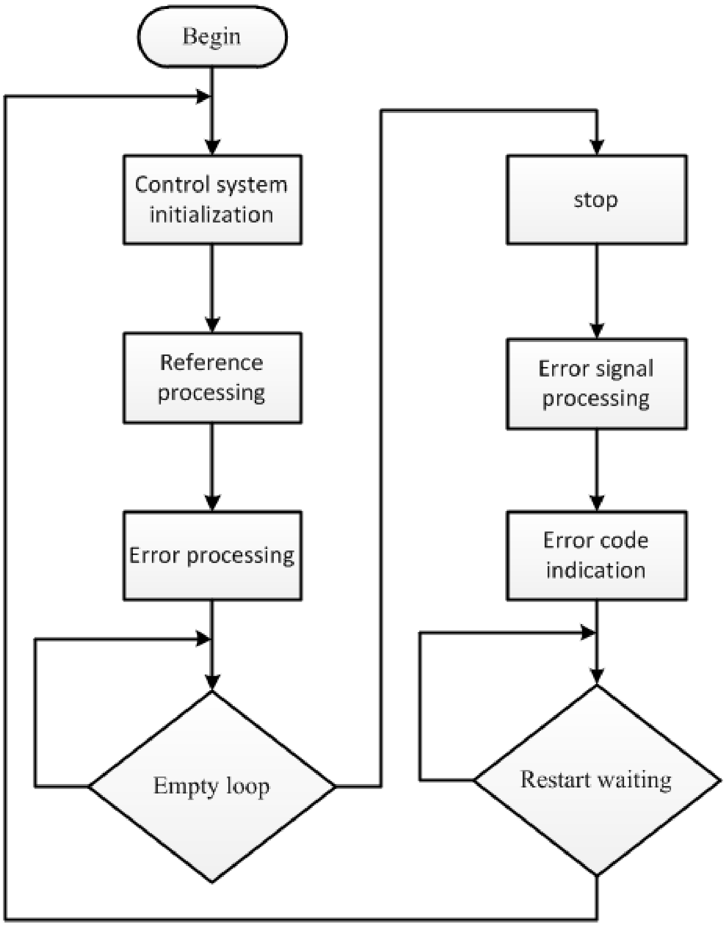

Figure 1 – The main program algorithm block diagram

The position that the use of the cutting machine main drive speed control device containing second-order polynomial in the numerator and the second order polynomial without free term in the denominator allows to improve the dynamic characteristics of the system during load-on compared to a standard proportional-integral control law is confirmed.

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COMPUTATIONAL MODELING THE NOISE ADC FOR THE BIOTECHNICAL CONTROL SYSTEM OF BIOOBJECTS' STATE

Annotation. Computational modeling of noise of ADC for estimation by Kalman filtering response of bioobject had been produced. The probabilistic model of the noise which is non stationary, i.e. has phase properties, had been received. The increasing quality of estimation the response of bioobject is supposed.

Key words: bioobject, response, ADC, noise, computational model.

Recently was researched the noise in the channels with digital signal processing (Dragan Ya.P., Yavorskii B.I., 1986). In the biotechnical control system of bioobject states, emerge necessary for computational modelling the noise analogue-to-digital conversation (ADC) for the bioobject response estimation by Kalman filtering.

We hold the noise

$$\xi_k = s_k^{(1)} - s_k^{(2)}, \tag{1}$$

where

$$s_k^{(1)} = \Xi_1\left[s_k(A,\mu)\right], \tag{2}$$

$\Xi_1[\cdot]$ – quantize operator with a small weight c of the least significant bit (l.s.b.) of digital binary code, $\mu = T_d / T_s$, T_d – discretization period, T_s – response period, $k = \overline{0,\infty}$.

$$s_k^{(2)} = \Xi_2[\mathrm{s_k}(A,\mu')], \tag{3}$$

where $\mu' = (T_d' + \theta)/T_s$, $T_d' > T_d$, $0 < \theta < T_d'$ – quantization time delay, and a weight c of the l.s.b. of digital binary code is a big. Quantize operators $\Xi_\bullet$ are given by expressions

$$\Xi_\bullet : s^{(\bullet)}(kT_d^\bullet) \in \mathbf{R} \to s^{(\bullet)}(kT_d^\bullet) \in \left\{e_m, m = \overline{0, n-1}\right\}_k, \tag{4}$$

where $\left\{e_m, m = \overline{0, n-1}\right\}_k \in \mathbf{GF}(2^n)$. Than inverse operators $\Xi_\bullet^{-1} : s^{(\bullet)}(kT_d^\bullet) \in \mathbf{GF}(2^n) \to s^{(\bullet)}(kT_d^\bullet) \in \mathbf{R}$ are not exists – $\Xi_1^{-1}[\cdot] \neq \Xi_2^{-1}[\cdot]$, so, emerges the error (1). We define

$$c = A/2^n \in \mathbf{R}, \tag{5}$$

where n – the number of bit of n-binary digital code, and $e_0, e_{1\cdot i} \in \mathbf{GF}(2^n)$, the zero and bases elements of the finite extended field of Galois with properties

$$e_{1i} \wedge e_{1j} = \begin{cases} e_0, & i \neq j; \\ e_{1i}, & i = j; \end{cases} \tag{6}$$

and $e_0 \wedge e_{1i} = e_0$, $i = \overline{1,n}$. Then the inverse transform

$$\Xi_1' : \tilde{s}_m = c \sum_{i=1}^{n} \beta_{im} 2^{i-1}, \beta_{im} \in \{0,1\}. \tag{7}$$

The error depends from the growing of s value in the time:

$$|\xi_\bullet| \in \begin{cases} (0,c), & ds(t)/dt\,|_{\max} \leq c / T_d', \\ (0, k\cdot c), & ds(t)/dt\,|_{\max} > c / T_d', \end{cases} \tag{8}$$

where $k \in \mathbf{Z}$. In dependence of μ' type (entire, rational or irrational) will be different means of cycle

$$\nu = \left[\phi(\mathrm{Q}(\mu'))\right]^{-1}, \tag{9}$$

where Q – complement of fraction to entire number, $\phi(\cdot)$ – Riemann function of values ξ_k repeating.

That is why values ξ_k are taken across period

$$N = \text{Ent}[(\mu')^{-1}], \tag{10}$$

where $\text{Ent}(\cdot)$ – entire part of number can be gathered to group $\xi_{i\eta}$, $\eta = \overline{1,N}$, $i = \overline{1,\nu}$. Because non-commensurable of harmonic's period $T_s = 2\pi/\lambda_s$ with period of discreet T_d' emerges a "running" of a phase. For a finite interval of view Θ the set of values $\xi(kT_d')$ in dependence from a class of a number T_s/T_d' (entire, rational, irrational), is split by the closing cycle condition

$$\text{Q}(\frac{p}{T_d'}) = \frac{\mu'}{\nu} \tag{11}$$

(where $p = T_d \text{Fr}(T_s/T_d'), \text{Q}(\cdot) = 1 - \text{Fr}(\cdot)$, $\text{Fr}(\cdot)$ – fraction part of a number) on subsets of power M_Ω that depend from value Θ (number of cycles). Values M_Ω for one cycle are equal:

$$M_\Omega = \left\{ \begin{array}{ll} T_s/T_d', & \mathbf{N} \\ \nu\,\text{Ent}(T_s/T_d'), & \mathbf{R} \\ \infty, & \mathbf{Q} \end{array} \right\} \ni T_s/T_d', \tag{12}$$

where $\text{Ent}(\cdot)$ – entire part of number. These quantities of error values are representative and generate a sequence of vectors $\xi(m,\omega), m = \overline{1,M}, M = \text{Ent}(T_s/T_d'), \omega \in \Omega$ – indices of subsequences with components of m-vectors. It was the base for definition of indicators mapping of indeces:

$$\text{I}: \{k\} \xrightarrow{\text{I}^k_{m,\omega}} \{m,\omega\}. \tag{13}$$

After this indicating, the set of realizations is received:

$$\xi(kT_d') \xrightarrow{\text{I}^k_{m,\omega}} \xi(m,\omega) \quad . \tag{14}$$

For $s_k^{(1)} = \Xi_1[A \cdot \sin(2\pi k\mu)]$ when A=1, T_s=1, T_d=0.02, c=0.0035, Θ=0.0095 (conditional units) is received the setof realization (14) (Fig. 1).

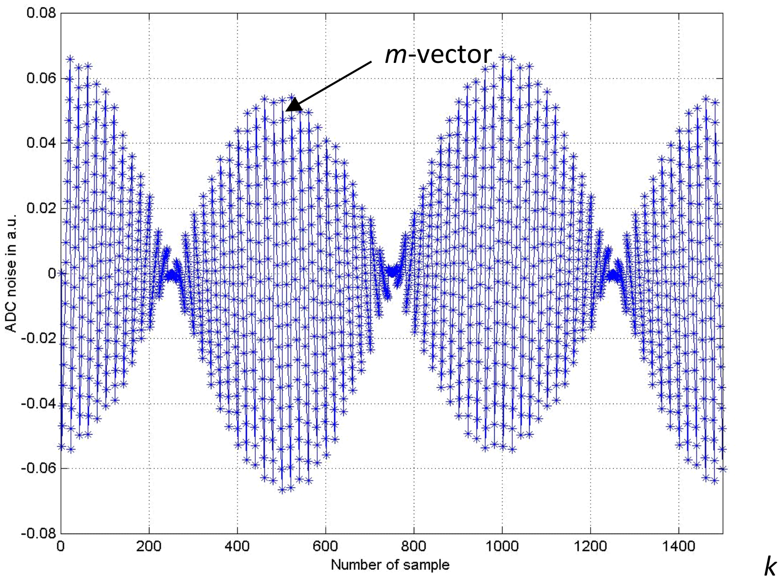

Figure 1 – Sequence of the m-vectors with components that together is value of stochastic process $\xi_{m\omega}$

We can say nothing about influence of permutations of components of *m*-vector, which is value $\xi_{m\omega}$ of (pseudo) stochastic process, i.e., the error of ADC. Distributions of probabilities the values of that process depends from the *m*, i.e., the probabilistic model of error in this case is no stationary process with the statistic that depend from the *m*. Thus, computational modeling of noise of ADC for estimation by Kalman filtering response of bioobject had been produced. The increasing quality of estimation the response of bioobject is supposed.

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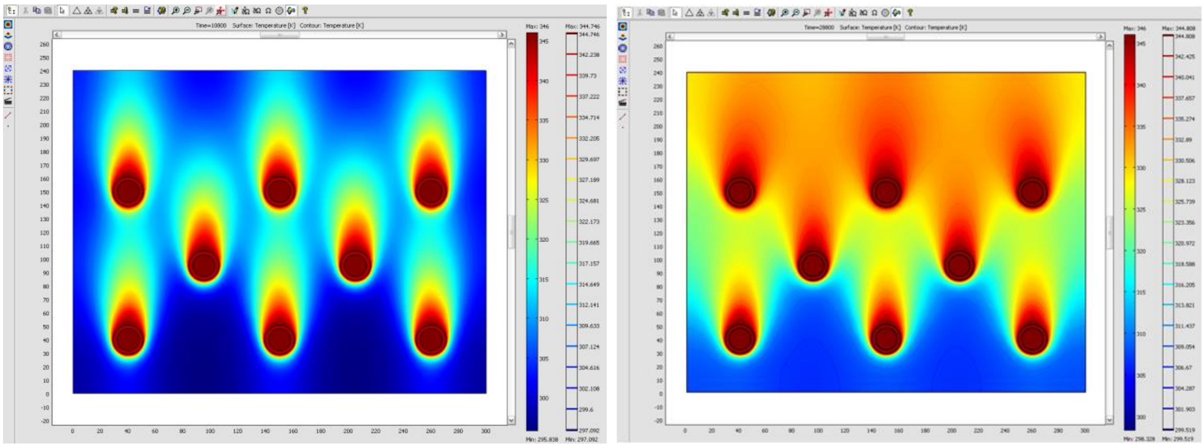
COMPUTER SYSTEMS FINITE-ELEMENT ANALYSIS FOR USE IN NUMERICAL STUDY OF PROCESSES OF HEAT IN THE HEAT ACCUMULATOR OF PHASE TRANSITIONS

The analysis of various sources [1-3], found insufficient information on the use of new methods of numerical modeling of transient physical processes that occur during phase transformations accumulating material. For the most part, to describe them using engineering methodology based on semi-empirical equations similarities and integrated methods, but they can not fully describe the character of a physical process in conditions close to real. In many cases this leads to incorrect results.

The paper modeling heat and mass transfer processes in heat accumulator element software system using COMSOL Multiphysics 3.5a. Description of the investigated processes of heat and mass transfer in the unit, was carried out on the basis of: Navier - Stokes law and Fourier heat equation, if the phase transition, which complemented the boundary and initial conditions.

As a result of numerical modeling heat transfer processes in the bulk material accumulating it was found that the contribution of convective flow in the overall picture of the melting material accumulating around the cylindrical heat source with a smooth surface, leads to increased process efficiency and speed melting of the material placed over the source of heat. Thus, the difference between the values of the temperature in the volume of the material of the upper and lower levels is within ± 5 ÷ 7 ° C (Fig. 1).



a) b)

Figure 1 – Dynamics of temperature fields in cross section volume accumulating material studied design heat accumulator: a – by 10800 c; b – 28800 c.

Conclusions.

As a result of numerical simulation resulting distribution of temperature fields and the direction of heat flow in the bulk material accumulating and found that:

- the presence of convective heat flow increases the efficiency of heat transfer and speed melting of the material placed over the heat source;

- the existence of dead zones in the corner of the lower volume of material accumulating points to the need to accommodate the first row of the heating pipe in the heat accumulator from the bottom and walls of the housing at a distance that does not exceed the limit radius distribution of heat.

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SWITCHED RELUCTANCE GENERATOR CONTROL SYSTEM

Annotation. Areas of application of switched reluctance generators are proposed. An approach to stabilizing the output voltage of the switched reluctance generator is presented.
Key words: switched reluctance generator, voltage stabilization, mathematical modeling.

Introduction. The switched reluctance machine is an electric machine in which the energy conversion is performed by changing the inductance of windings located on the salient stator poles when moving the toothed rotor relative to them. The supply of the switched reluctance motor (SRM) is carried out from an electronic converter (commutator), which alternately switches the motor windings in accordance with the rotor moving. To control the SRM electronic converter the microprocessor is used.

The switched reluctance motor is a special machine, which have a certain advantages over classical electric machines. Among them, the most significant are: simple design, no permanent magnets and windings on the rotor, high energy efficiency, reliability and the ability to work in a wide speed range.

The switched reluctance generator (SRG) has all of the above-mentioned advantages in comparison with classical generators and, as a result, it can find its use in various applications. For example, it can be used as a starter-generator for electric vehicles, or as a generator of autonomous power systems. Due to its good operational properties and high efficiency over a wide speed range, the SRG can be considered as a wind generator.

The purpose of the work is to develop a control system for the switched reluctance generator to ensure its stable operation. The main task of the SRG control system is to stabilize the output voltage, depending on the load change.

Essence of research. The regulation of the output voltage of the switched reluctance generator can be carried out by changing the firing angles, or the phase current level [1].

In [2], it was reported that the SRG voltage regulation by changing the firing angles in practice is inefficient, since the output current is very sensitive to small changes in the turn-on and turn-off angles. The control system that controls the output power of the switched reluctance generator by regulating the phase current level with fixed turn-on and turn-off angles by means of the PI controller is presented. This control system provides a stable output voltage of the SRG with rated power of 30 kW when the load is changed only in the range from 20 to 30 kW.

However, the operation of the switched reluctance generator with fixed firing angles is unstable and the output voltage may increase or decrease exponentially depending on the load [3].

A typical switched reluctance generator control system is shown in Figure 1. The output voltage V_{DC} is fed back and compared to its reference value V_{DC}^*. The controller regulates control variables such as the turn-on/off angles θ_{on}/θ_{off} and current set point I_{HI} depending on reference voltage and the rotor speed ω. The SRG, which represents the semiconductor converter and the machine, generates current I_0. The difference between I_0 and the load current I_L charges the converter capacitor C, the charge of which determines V_{DC}.

A control scheme, in which phase switching is performed when the phase current reaches the set point while the firing angles remain unchanged, is proposed. The regulation takes place according to the definite relationship between the voltage, the current set point and the load resistance for the reference voltage as the difference between the reference and the actual voltage. This scheme is relatively simple, but for its implementation, it is necessary to carry out a series of calculations by simulation or experimentally to obtain the relationship between the threshold values of the phase current, the load and the output voltage. These dependencies in the form of a two-dimensional array are loaded into the memory of the controller, which regulates the threshold value of the current, depending on the reference voltage and load. The output converter capacitor serves to smooth the output voltage ripple.

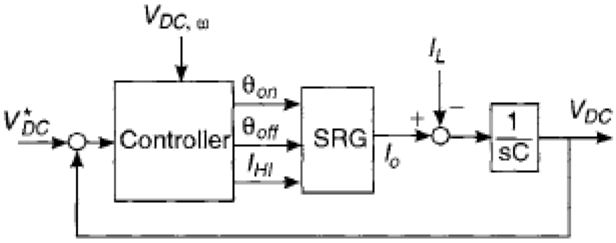

Figure 1 – Generator control system

The research of the switched reluctance generator control system is done based on mathematical modeling. To achieve the objectives, the theoretical studies using the field and the finite element methods, the theory of linear circuits, the modeling based on differential equations and block diagrams is made.

Conclusions. The proposed control system of the SRG is different from previous ones, which ensures stable output voltage at any reference value in the whole load range. Furthermore, for voltage regulation with fixed firing angles to ensure the stable operation of the switched reluctance generator it is sufficient to use a simple rotary encoder instead of a high-resolution resolver.

If it is necessary to use the SRG in systems where the speed of the prime mover varies over a wide range, it is necessary to realize the output voltage stabilization also depending on the rotor speed.

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USAGE OF UAV FOR THE PRECISION FARMING

Rational uses of mineral fertilizers in crop production has been particularly common in Ukraine in recent years. Obtaining high yields of cereals and high-quality products is often not possible without ensuring the timely fertilizing of crops. But in agrophytocenosis plants require nutrients which are often of a random nature. Adding the necessary doses of fertilizers in accordance with the requirements of the plants is an integral part of precision farming technology. But today, new technologies require agrochemical research express methods. Classical methods related to chemical analysis are not adapted to mass research because they can be time-consuming and may not always be applied. At the same time, the actual period for fertilizer feeding is only a few days. An alternative to the use of chemical methods is the research of leaf diagnostics, when plant tissues are determined by means of problems in plant nutrition. Leaf diagnostics, in particular the definition of such vegetation indices like the NDVI, are actively used in space research, which was true for large agricultural producers. Previously, research of the diagnosis leaves using a spectrophotometer was conducted [1], but the complexity of the equipment and problems with radio frequency correction become a serious obstacle to the mass adoption of these techniques.

The appearance on the domestic market of relatively inexpensive unmanned aerial vehicles (drones) with a flight altitude of several hundred meters gives farmers a fundamentally new research tool with fundamentally new features. For the use of drones when conducting diagnostic leaves it is necessary to solve a number of technical problems on the methodology of this equipment's usage. The purpose of re-search is the study of drones' modes for monitoring the condition of the plant, providing them with nutrients, namely the study of the influence of the flight's height on the brightness ratios RGB planting.

Experimental studies were carried out from the 20th to the 24th of May 2016 in Kiev Svyatoshinsky district, Kyiv region (GPS coordinates are 50 deg 19 '49,00 "N, 30 deg 24' 40,00" E). Flight altitude was determined from the readings of the control panel of the drone and manually was recorded in the journal of the experiment. The monitoring was conducted in the period from 14.30 to 17.30 hours. Artificial lighting study sites were not used. There has been usage of drone for the monitoring. The ob-jects of monitoring were selected from field plots sown with winter wheat in the growing stage "earing" and a dirt road with a visually clear boundaries, the location of which was determined from the characteristic visual references. In conducting re-search, the drone was positioned approximately midway between the studied areas of the field and the road.

The studies were conducted at the altitude range of 200 m. According to the passport the tool could reach a greater altitude. However, in practice at altitudes above 300 m a problem was discovered with the control device, due to a clogging noise on the control radio channel from the third-party sites, such as the high-voltage transmission line. In addition, at altitudes above 200 meters there were difficulties in fixing guidelines which were selected for the study areas, at the expense of achieving the upper limit of the resolution of standard cameras. Fixing the RGB values was carried out by regular PHANTOM VISION FC200 digital camera with a resolution of 10.8 × 106 pixels. In order for the research to improve the accuracy of the results the manual mode was changed, the exposure time of the camera was automatically recorded in exiff file.

The experiments took into account the presence of shadows from the clouds on the test section of the field. The subject that was partly in the shade was not studied.

Soil in the monitoring zone was in a dry air condition. The test section of the field road had no clearly defined humps and hollows, traces of puddles or vegetation. The road was previously used for the passage of heavy wheeled agricultural ma-chines. As a consequence, the soil was compacted.

The processing of the results was carried out in the laboratory using the proprietary software Land damage expert, described previously [2, 3]. In monitoring, the camera's digital zoom function was not used. The study section was selected in manual mode from a total picture. Official photo data was automatically entered in the exiff file and was read by an on-line service [4].

Figure 1 shows the results of the relation between R luminance factor of wheat field and the magnitude of Light Value at different heights drone flight. As can be seen from the data, the dependence of the red component of the luminance factor of the magnitude of Light Value is linear (value adjusted r-squared ≥0,992). According to G and B components the dependence also has a linear character. With increasing the height of the drone above test site of wheat field, the luminance values of coefficients is reduced. This is not observed for the studied area in a dirt road. This leads to the conclusion that the coefficients uniform brightness of the object stable in a range of heights up to 200 meters as the most suitable for remote-controlled drones class micro. For values of Light Value ≤10,5 R value of the luminance factor, which has an 8-bit reached the boundary values and is no longer subject to change, which explains the stabilization at 253-255.

In our opinion, there is a relationship between the coefficients of the brightness and the drone flight altitude due to the fact that the field is not uniform in the frame, in addition to plants and shade created by them, the lit ground gets into the shot.

In this case, air dry ground is considerably lighter than plants. With increasing distance between the drone and the resolution of the camera, field capacity decreases, whereby the ground is fixed to a lesser extent and accordingly varies the average value of the luminance factor. Also worth noting is that the wet soil is much darker than the plant and, accordingly, an inverse relationship is observed after the rain. Accordingly, for precise measurement of the brightness coefficients when leave diagnosis is necessary to filter sheet portions corresponding to the ground.

The studies were conducted both in the clear sky, and in cloudy weather. In both cases, Light Source value indicated in the manual mode as an Cloudy, and Fine Weather. Significant difference was recorded in the red and green components. The blue component in the case of the values of Light Source - Cloudy value B brightness ratio was significantly lower, which is undesirable for metrological reasons. Apparently, this is due to the conversion algorithms of initial information given in the JPEG format camera manufacturer.

Conclusions.

1. The dependence of the brightness coefficients in the RGB color formation additive function from the parameter Light Value at altitudes up to 200 meters is linear.

2. In determining the brightness coefficients of plants for leaf diagnosis, the presence of soil in the frame must be taken into account.

3. With an increase in the influence of color on the ground monitoring the height of the brightness value of the coefficient is reduced.

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OBJECTIVE CONTROL OF MOBILE ROBOT GROUP IN THE LIMITED COMMUNICATION RANGE CONDITIONS

Annotation. The minimal-time pointing problem of a mobile robot group by a number of distinct targets arbitrary distributed within some area is considered; it is assumed that the number of mobile robots is equal to the number of targets. Each mobile robot has a communication subsystem with a limited range and a-priori information about every target position. The decentralized algorithm for the mobile robot system's objective control which ensures target assignment to each mobile robot is proposed.

Key words: mobile robot; objective control; communication subsystem.

Introduction

The system consisting of the mobile robot group, each of which is equipped with a transceiver with a limited range, is considered. Robots are system agents which are arbitrary distributed on a surface area; targets are distributed on the same area. The task is to distribute the targets among the agents in such a way that the agents reach their targets for the total minimum time. Since the a-priori distribution of "agent-target" pairs does not exist, this task must be solved taking into account the presence/absence of communication between agents and their movement. We will call this problem the objective control problem. In the centralized formulation, this problem is known in the literature on combinatorial optimization [1], as the problem of maximal coverage.

Basic material

We formalize the statement of the problem. It is necessary to distribute k targets among the n robots included in the mobile robot system (MRS) ($n = k$). The targets and mobile robots are randomly located on the surface segment $\varepsilon(n) = [0, l(n)]^2 \subset R^2$, where $l(n) > 0$. In the process of such distribution, for each target $q_j \in Q$, a single mobile robot $i \in I$ must defined for which the location is $p^{[i]}(t) = q_j$ beginning with the certain point of time $t \geq T \geq 0$. If the solution of the problem starts at the time $t_0 = 0$, then T is the time of its solution completion. In this case, there should be taken into account temporal changes of the information network topology, due to the peculiarities of the terrain, the limited range of communication, etc.

To solve the problem, a decentralized target control algorithm is proposed.

We will assume that each MRS agent has complete a-priori information about the location of all targets, and that the information of targets location is stored in the memory of each agent as an array, and not as an unordered set. We will also assume that each robot must achieve only one target. The transceivers of the mobile robots operate in the limited radius r_{comm}, data exchange is carried out in accordance with the schedule. All messages in the mobile robot system are transmitted and received simultaneously.

According to this algorithm, each mobile robot $i, i \in I$ initially calculates the optimal route (the traveling salesman problem is solved), which connects n targets, as a result of which the set of targets is converted into an ordered sequence. Then each mobile robot i determines the nearest target, as well as the next available target of the route, and the target preceding the nearest one.

Mobile robots move along the route searching the next available target, exchanging relevant information during communication sessions in accordance with the schedule, and resolving the conflicts - cases where one target is assigned simultaneously to two mobile robots. If agent i is closer to the target than agent j and their range zones overlap, then after the communication session, the movement to this target will be continued only by that agent whose distance to the target is shorter.

The simulation of the algorithm was carried out for the case when the number of agents and targets was 20. Also, the scalability of the algorithm was considered. In this case, the area of the site was defined as $4r_{comm}^2 \times n$, the number of simulation sessions was 30. The simulation results showed that the proposed algorithm for the MRS objective control scaled well.

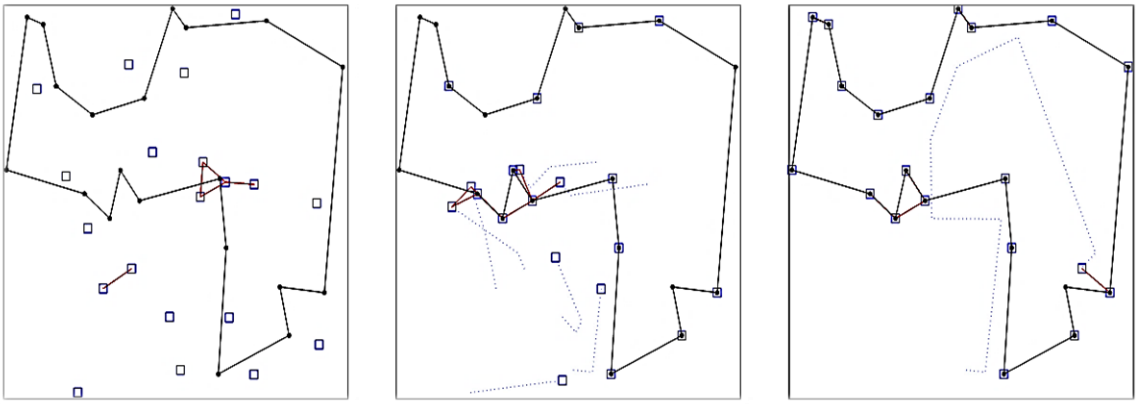

Figure 1 – Simulation of the problem solution for the system of 20 mobile robots.

Conclusions

A decentralized objective control algorithm that ensures that the mobile robot group achieves all the specified targets for the smallest possible time and takes into account changes in the network topology is proposed. An estimation of the algorithm for changing this time with an increase in the number of robots and targets is made. The obtained results showed that the proposed algorithm can be effectively used for control the mobile robotsystem for various purposes.

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UDC 62-7

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CONTROL MODULES PROGRAM REALIZATION IN ACCORDANCE WITH ISA-88 STANDARD

Annotation. The frame work is a set of interrelated elements of library functions and function blocks, which are described at their interface level, interaction principles and algorithms of functioning. It is assumed that IEC 61131-3 languages will be used for the implementation of framework for the particular controller, but it is not a prerequisite. Set of frame elements can be expanded and supplemented with additional functionality without infringing the general principles.

Key words: ISA-88, control module, controllers channel, process variables, actuators.

Introduction

Developed a concept based on the implementation in PLC object model equipment, according to the concepts of ISA-88, ISA-95 and ISA-106. Each equipment entity is a functional block or function, and a set of data, that can realize the exchange with the upper level. The data structure and behavior of the function/FB compatible with defined in ISA-88, that is based on machines states, modes and interfaces defined in this standard. The procedural elements and basic control are also based on standard terms. That the developed framework is a library interrelated elements that ensure the implementation of the basic set of control module and equipment module, regardless of the control object and determine the mechanism of their implementation in higher-level objects.

Materials and methods

The default equipment entity at level of control module are proposed to provide:

- controllers channel (DICH - discrete inputs, DOCH - discrete outputs, AICH - analog inputs, AOCH - analog outputs, COMCH - communication channels) for diagnostic channel and binding logical channels to physical;
- process variables (AIVAR - analog input, AOVAR - analog output, DIVAR - discrete input, DOVAR - discrete output) for complete information processing in process, including binding to channel, filtering, scaling, inversion, etc.; for easy debugging process; for functions of simulation modeling; for technological functions of alarm;
- Actuators (valves, control valves, motors, pumps): for control functions with feedback; for easy debugging process; for functions of simulation modeling; for technological functions of alarm; for conducting statistics.

All of the above elements in terms of the ISA-88 are the control modules, but in terms of ISA-106 are the devices. To unify the titles, we use the terminology ISA-88 as valid today. All control modules form a three-level hierarchy that allowed standard ISA-88.

Results and discussions

The lowest level of control modules provides a level of abstraction from the hardware. That realization of this level depends on the chosen platform and method of implementation. Elements of the control module type "channels" are all arrays controller channels, regardless of their location and involvement in the process. Each array element is uniquely identified by a number, a binding to the physical channel is individually. The control module of the type "channel" their values are tied to the physical value of a particular channel and perform the following functions:

- Provide diagnostic information to higher levels of control modules such as a sign of authenticity, and the if possible reasons for refusal channel;
- Permit mode forcing value;
- Indicate the fact of binding to channel process variable.

The control module of the second level of the type "technological variables" can be attached to the channel of the same type by their number. Thus binding process variable to the channel is dynamic, allowing you to change the location of a particular physical connection of the sensor/actuators in the event of failure part of the system. In addition, this switch can be programmed. "Process variables" are higher in the hierarchy of controls then "channels". All diagnostic information are transferred from the "channel" to "process variables". Implementation of this level is independent of the hardware characteristics of the controller, since all platform-dependent subtleties implemented at "Channel" interface which is standard. "Process variables" provide the following functionality:

- Binding to the channel by its number;
- Disconnection of service (deactivation variable);
- Tracking authenticity of value for the error bound channel, out of range of measuring value, etc.;
- Diagnostics of the channel (transfer of diagnostic information from a connected "channel" on the upper level);
- Processing of input / output values: scaling (including piecewise linear interpolation), filtering, inverting;
- Availability of manual change mode (forcing) according to ISA-88;
- Availability of simulation mode in which to input variables value changes upper level control modules and for output variables, is freezing values output channels;
- Processing of alarms (ISA 18.2): Response thresholds for triggering consideration of delay, hysteresis, forming a common bit system alarm/warning;
- Configuring alarms processing (ISA 18.2): setting alarm values, types of alarms (alarm/warning/channel error), temporary removal from service alarm.

The control modules of third level are the actuators, regulators, etc., and include basic control functions (according to the terminology of ISA-88). Each control module provides a two-way interaction with the "process variables" for recording and reading. This allows for a given level of implementation of specific functionality for a specific control module, and provide the following features:

- Take into account the state of "process variable" (normal/alarm/authenticity) and diagnostic information in the control logic execution control module;
- Simulation of the control module using it included modeling algorithm (if necessary):
- Advanced model-based diagnostic process;
- Model-based control;
- Work in simulation mode for demonstration/training or adjustment of system;
- Inclusion in simulation mode control module and all its related control modules lower;
- Statistical information (depending on the type of control module).

Conclusions

Among the most significant advantages over older approaches to software development for PLC, there have been the following:

- Reducing the time of commissioning works;
- Reducing the time changes in project;
- Reducing the time malfunctions (some problems had not even manifested);

The above facts were shown only at a particular site and only at partial implementation of the proposed ideas. However, it should be noted that the development of the framework requires a lot of time, which offset a decrease in the time of its re-use and commissioning.

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DIGITAL LEARNING CONTENT IN THE STUDY OF PROGRAMMING

Annotation. Problems of creating, managing and combining local and global learning e-resources in the study of programming are considered. Teacher's and student's point of view on the use of e-learning materials is analyzed.

Key words: programming, learning, study, electronic resources.

Introduction, formulation of the problem.

Learning of programming requires finding new ways to manage educational process. Now teachers are not only lecturers and learning content creators, but also the organizers who involves students to the use digital educational resources. Major problems:

- Not all teachers know modern open educational resources;
- Not all students fluent in English;
- The habit of most students to work with only one manual;
- Each course has own features that determine the optimal ratio of local and global resources;
- Wide choice of local and global educational content often leads to confusion of students: what resource is better? How to choose? How and what part of resource to use? It can take too much time.

In view of this, the analysis of student's point of view on a use of different types of learning resources is useful. In particularly, if the problem considered in due to the level of student success.

Method of solving the problem.

We have decided to expand the list of recommended external training resources. At the end of the year we have taken the survey for students of B.S. specialty "Economic cybernetics", which learned computer programming.

Questionnaire had following clusters:

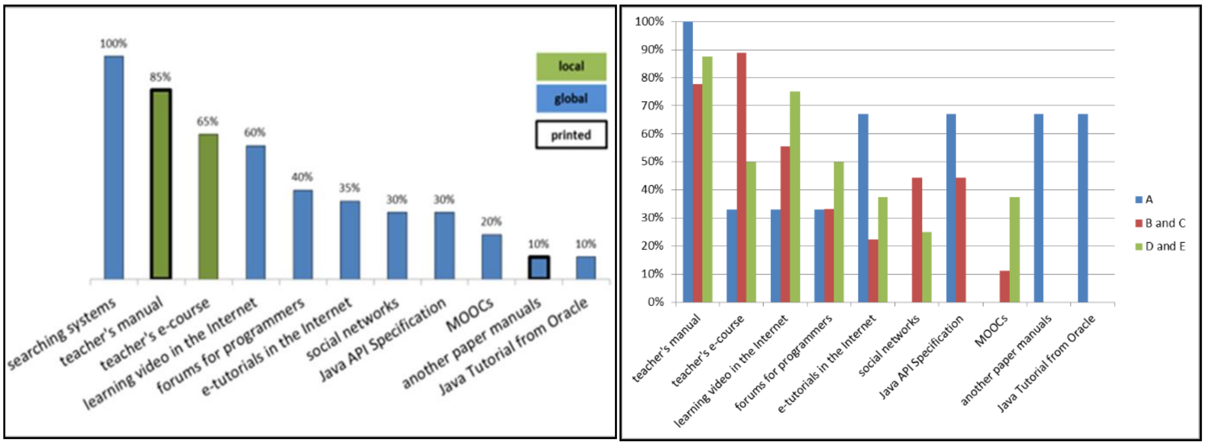
- Optimal ratio of time spend: in the classroom, own training, consultation with teacher;
- How often students visit the teacher's e-course;
- Use of different types of learning resources;
- Are students know and/or registered on some MOOCs;
- Importance and usefulness of different types of learning resources;
- Completeness and sufficiency of various types of resources;
- The need for external training resources;
- The main problem in the study of computer programming;
- Suggestions.

Essence of research.

Most of students believe that most of the time in the study of programming must be a work in the classroom (44%) and independent work (41%). Note that an earlier verbal survey of students on specialty "Computer Science" made a very different picture – students believe that independent work have to take at least 70-90% of the learning time.

Fig. 1-A show that the teacher's printed manual and e-course, and learning video on the Internet is the most popular. Of course, all use Google and similar search engines.

Best students (grades A, B) are using more types of resources, weaker students more like videos and teacher's content. Teacher's e-course most demanded by average student. A social network and MOOCs are not necessary for best students (Fig. 1-B).



A B

Figure 1 – Different learning resource using

Different resources have different usefulness for students. In our case the resources created by teachers are most important them. But different students have different estimate (Fig. 2). The best students consider that other manuals are useful, including official Java Tutorial. Average level students are guided to the teacher resources, but less read other guides. Weak students oriented to get information fast, so, they prefer a printed manual, video and tips in the forums.

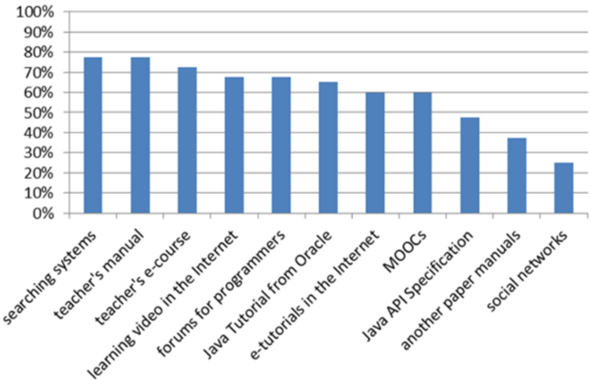


Figure 2 – Usefulness of learning resource

The questionnaire included the question: "If you can use this source only for studying programming, what level of sufficiency of the source?". In general, the teacher's printed manual is most acceptable (~60%). In the other hand, only 10% students consider that teacher's manual and e-course is enough. That are the students who have grades D and E.

Conclusions. We can see that printed guides are still needed; weak students more like a training video, mid-level students most used teacher's e-course, best students are also working with other specialized manuals; for the best students it is important to work with a variety of resources, for mid-level students - a most complete textbook and e-course, weak students wants obtain demo video and quick response; e-course should be developed with a focus on middle level students; all types of learning resources are not sufficient, it is necessary to use additional resources.

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Section 4 "Controlling the aerospace craft, marine vessels and other moving objects"

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PREDICTION OF AIRCRAFT TRAJECTORY UNDER HETEROSCEDASTIC DISTURBANCES

Annotation. The research examined the possibility of using the adaptive exponential filter based on Brown's model for determining forecast values of aircraft trajectory. This filtering algorithm can be integrated into the data processing system of fixed radar systems as a supporting and clarifying element.

Key words: exponential smoothing, heteroscedasticity, aircraft, smoothing factor.

The definition of the aircraft coordinates and tracking of its trajectory is a relevant issue whilst the airspace is filled with a huge amount of objects. Among all issues that occur in addressing this problem the heteroscedastic active and passive disturbances are defined. The purpose of the research is to analyze the possibility of the integration of the adaptive exponential filter that is based on the Brown's model for determination and forecasting of the aircraft trajectory. The system of coordinates displacement definition can be chosen as an object for integration with the adaptive filtering data processing algorithm. The parameters for definition of the target are the radial distance D, the azimuth angle α and the polar angle β. These coordinates in a case of the aircraft trajectory definition can be treated as time functions $D(t)$, $\alpha(t)$, $\beta(t)$. Any of this functions can be presented as $x(k)$, where x is a value of the signal, which is characterizing one of the coordinates and k is a time sample number.

According to the Brown's model [1] the signal value at a certain time moment consists of two components. The first component is the product of the current signal value and weight coefficient α. The second component is a product of the difference in the form $(1 - \alpha)$ and the smoothed value of the signal in the previous time moment (k– 1):

$$\hat{x}(k) = \alpha \cdot x(k) + (1-\alpha) \cdot \hat{x}(k-1), \qquad (1)$$

In the proposed model of adaptive filter in gal go rhythm we used double exponential smoothing (1)for getting better filtered signal values. Double exponential smoothing gives us an opportunity to get a linear prediction for m steps:

$$\hat{\hat{x}}(k+m) = \hat{\hat{x}}(k) + m \cdot \Delta t \cdot \dot{\hat{\hat{x}}}(k), \qquad (2)$$

where $\hat{\hat{x}}(k+m)$ – for ecasted smoothed signal value for m steps; Δt – time between signal measurements; $\dot{\hat{\hat{x}}}(k)$ – derivation of double smoothed signal.

Among the drawbacks of exponential smoothing we should determine the presence of the following error. In the proposed algorithm the compensation of this error was provided by filters connection according to nonius extension structure principle [2].

Since input disturbances are heteroscedastic the data processing algorithm should adapt depending on the disturbance amplitude changing. The adapting process works in the next few steps. The sum of useful signal and disturbance is fed to two filtering contours with different smoothing factors α. After the $\hat{\hat{x}}(k+m)$ values are got from each contour they are delayed for m steps. The forecast error is defined by receiving the difference between input signal $x(k)$and $\hat{\hat{x}}(k+m)$ signal value on each contour. We can make a conclusion about the contour that provides better filtration quality accumulating data about forecast error during some period of time. After that both smoothing factors can be decreased or increased depending on which contour showed lesser forecast error. The filtration process and forecast value definition were modeled in the Matlab environment. The results of the modulation are presented on the following figure:

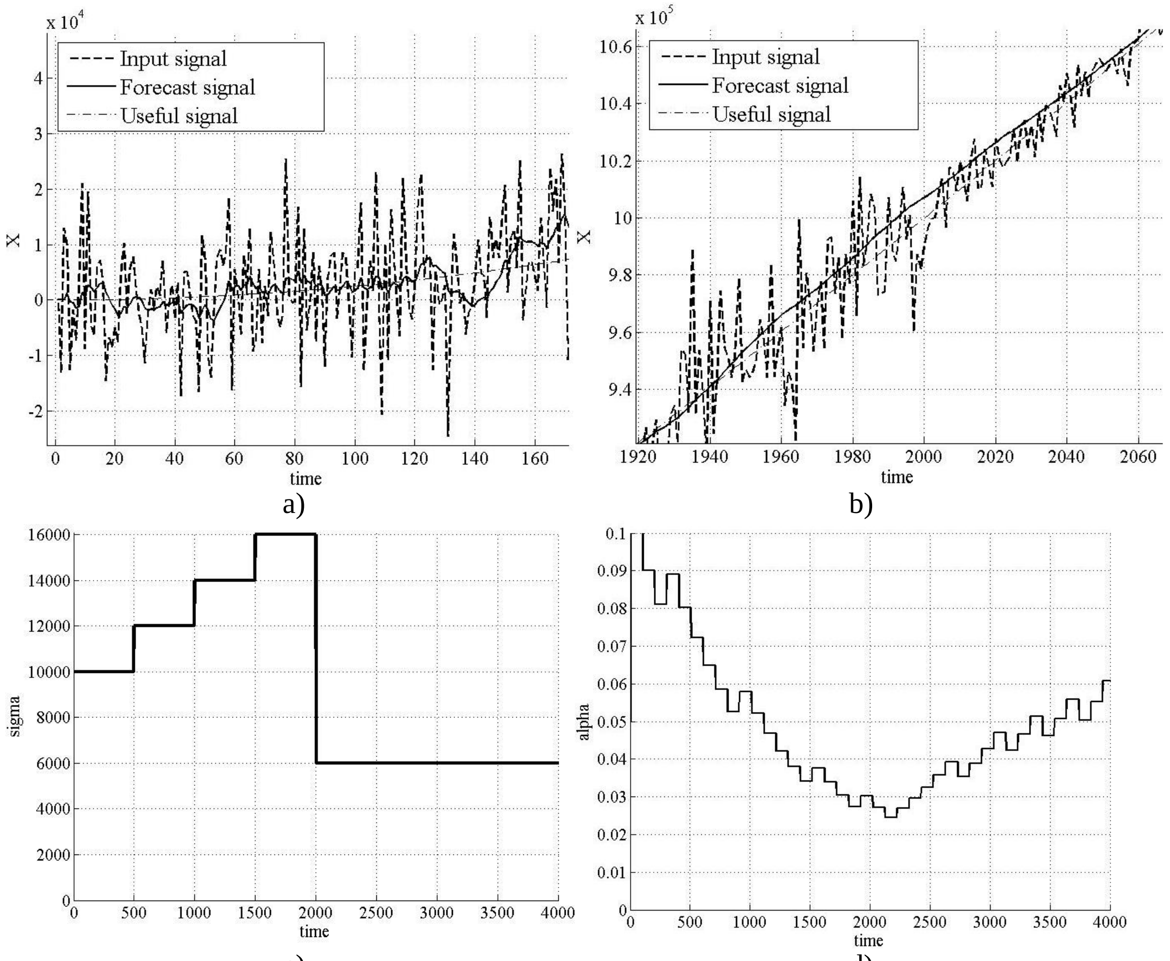

Figure 1 – Graph of mathematical modelling: a) input signal, predicted signal, useful signal (k=0…170); b) input signal, predicted signal, useful signal (k=1920…2065); c) characteristic of disturbance amplitude (*sigma*) changing; d) graph of smoothing factor (α) changing in process of adaptation.

Described data processing algorithm can be used for determination of predicted aircraft coordinates. In matters of advantages the algorithm flexibility provided by possibility of changing adaptation parameters, as well as availability of adaptation itself, which allows to filter signal value in condition of heteroscedastic interferes should be noticed.

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THE CORRECT VALUATION OF THE LINEAR COMPONENT OF THE NONLINEAR AERODYNAMIC DEPENDENCIES

Annotation. The paper is dedicated to the problem of objective identification of high aerodynamic coefficients (ADC) of an aircraft on the accuracy of which depends the quality and stability of the aircraft control systems and, consequently, the safety of flight.

Key words: identification, aerodynamic coefficients.

Unbiased high-precision aerodynamic coefficients *(*ADC) estimation as partial derivatives, that is, linear component of nonlinear dynamics of PM and LM of aircraft. ADC is a derivative of the moment or force at the relevant variables, taken at a fixed point in space - time. This ADC definition is identical to non-linear models coefficients only if the deviation tends to zero. But then the "noise-signal" ratio grows to infinity and ADC estimation will become impossible.

The compromise between the linear model which is true for small deviations and complete nonlinear nonstationary model which is for all modes of flight will be the model presented by the first and second members of nonlinear model's Taylor decomposition. For example, for $m_{z_1}(t)$:

$$
\begin{aligned}
m_{z_1}(t) &= m_{z_1}(t_0) + \frac{\partial m_{z_1}}{\partial \alpha}\Big|_{t_0} \Delta\alpha(t) + \frac{\partial m_{z_1}}{\partial \bar{\omega}_{z_1}}\Big|_{t_0} \Delta\bar{\omega}_{z_1}(t) + \frac{\partial m_{z_1}}{\partial \delta_B}\Big|_{t_0} \cdot \Delta\delta_B(t) + \\
&+ \frac{1}{2}\cdot\frac{\partial^2 m_{z_1}}{\partial \alpha^2}\Big|_{t_0} (\Delta\alpha(t)) \times \left[+ \frac{\partial^2 m_{z_1}}{\partial \bar{\omega}_{z_1}}\Big|_{t_0} \left(\Delta\bar{\omega}_{z_1}(t)\right)^2 + \frac{\partial^2 m_{z_1}}{\partial \delta_B}\Big|_{t_0} (\Delta\delta_B(t))^2 \right] + \\
&\frac{\partial^2 m_{z_1}}{\partial \alpha \partial \bar{\omega}_{z_1}}\Big|_{t_0} \cdot \Delta\alpha(t)\cdot\Delta\bar{\omega}_{z_1}(t) + \frac{\partial^2 m_{z_1}}{\partial \alpha \partial \delta_B}\Big|_{t_0} \cdot \Delta\alpha(t)\cdot\Delta\delta_B(t) + \frac{\partial^2 m_{z_1}}{\partial \bar{\omega}_{z_1} \Delta\delta_B}\Big|_{t_0} \cdot \Delta\bar{\omega}_{z_1}(t)\cdot\Delta\delta_B(t).
\end{aligned}
\tag{1}
$$

Equation (1) takes into consideration asymmetry of pitching and divingmodes. But a large number of its members, mutual correlation, limitations andproximity of measurements and limited regime time by change in speed and heightare making the task of evaluating all ADCs impossible. For more accurate ADC estimation let us plan the experiment so that all the variables of the equation (1)were close in form to steps and exponent. Then (1) can be approximatelyrepresented as follows:

$$
\begin{aligned}
&\Delta m_{z_1}(t) \cong a_2\Delta\alpha(t) + a_1\Delta\omega_z(t) + b_1\Delta\delta_B(t), \\
&where\ a_1 = m_{z_1}^{\bar{\omega}_z} + \left[m_{z_1}^{\alpha\bar{\omega}_z}\Delta\alpha(\infty) + m_{z_1}^{\bar{\omega}_z^2}\Delta\bar{\omega}_{z_1}(\infty) + m_{z_1}^{\alpha\delta_B}\Delta\delta_B(\infty) \right]; \\
&a_2 = m_{z_1}^{\alpha} + \left[m_{z_1}^{\alpha^2}\Delta\alpha(\infty) + m_{z_1}^{\alpha\bar{\omega}_z}\Delta\bar{\omega}_{z_1}(\infty) + m_{z_1}^{\alpha\delta_B}\Delta\delta_B(\infty) \right]; \\
&b_1 = m_{z_1}^{\delta_B} + \left[m_{z_1}^{\delta_B\alpha}\Delta\alpha(\infty) + m_{z_1}^{\delta_B\bar{\omega}_z}\Delta\bar{\omega}_{z_1}(\infty) + m_{z_1}^{\delta_B^2}\Delta\delta_B(\infty) \right].
\end{aligned}
\tag{2}
$$

By changing the $\Delta\delta_B(\infty)$ amplitude we can proportionally change the offset of a_1, a_2, b_1 coefficients with respect to required ADCs: $m_{z_1}^{\bar{\omega}_z}$, $m_{z_1}^{\alpha}$, $m_{z_1}^{\delta_B}$.

Example. Fig. 1a shows seven modes of different amplitude of changes elevator δ_B, angle of attack $\alpha(t)$ and angular velocity $\omega_{z_1}(t)$ of the aircraft M-17 in pitching movement. Complete dependence $\dot{\omega}_{z_1}(t)$ on $\delta_B(t)$, $\alpha(t)$ and $\omega_{z_1}(t)$ is similar to the model (1). In each of the modes evaluation model coefficients $\hat{\beta}_j$, $j = 1,2,3$ are calculated and biased due to the model approximation. Aperiodic stability reserve $\hat{\sigma}_n$ is calculated using them.

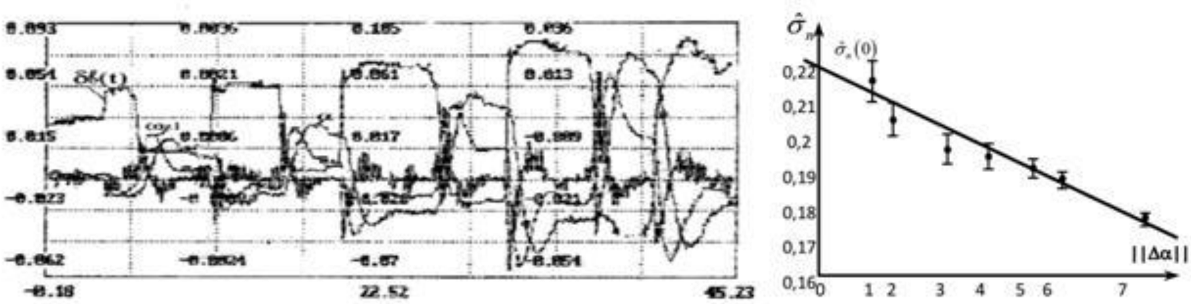

Figure 1: a) Oscillograms of changes of elevator, angle of attack and angular velocity;
b) Dependencies $\hat{\sigma}_n(\|\Delta\alpha\|)$

Reserve was approximated by OLS-dependence (3) in $\|\Delta\alpha\|$ function (Fig. 1b):

$$\hat{\sigma}(\|\Delta\alpha\|) = 0{,}22 - 0{,}075\|\Delta\alpha\|, \quad (3)$$

where 0,22 is required unbiased estimation.

Simple averaging results in understated estimate $\hat{\sigma}_n = 0{,}188$. Further $\hat{\sigma}_n$ refinement is achieved by approximation of $\hat{\sigma}_n(0)$ by regression dependence on other flight parameters (speed, height etc.).

So, Table. 1 shows the linear regression dependence of ADC on the initial angle α (coefficient a_1) and its derivative (coefficient a_2) of the AN-72 plane. Considering only α and $\dot{\alpha}$ made it possible to multiply the accuracy of ADCestimates by two on average. Table 2 contains data which confirms effectiveness of stability reserve σ_T refining by dependence on different flight parameters ΔX.

Table 1

ADC estimation dependence on α and $\dot{\alpha}$

DC	a_0	a_1	a_2	FCS appr.	Average	FCS avg.
$m_z^{\bar{\omega}_z}$	-8,54	-0,0112	0,01	-10,61	0,02	
m_z^{α}	-0,0092	0	0	0,007	-0,0091	0,007
$m_z^{\delta_B}$	-0,0161	-0,0012	0	0,003	-0,02	0,0009
$m_z^{c_y}$	-0,0873	-0,0029	0	0,004	-0,0928	0,006
σ_n	-0,2301	0,0071	0,0001	0,001	-0,2119	0,002

Table 2

Reserve refining by dependence on different flight parameters

Plane type	СКП, %		Dimension of ΔX.	Modes amount
	models	average		
AN-72	5	102	6	190
IL-86	7	31	2	25
TU-154	4	13	4	70
MIG-29	7	50	4	50
M-17	0,5	1,5	2	15

In general, for correct identification problem statement it is important to distinguish between signal and parametric approaches. The generality of them is in minimization of $\varepsilon^T\varepsilon$, the difference is in the requirements for $\varepsilon^T\varepsilon$ functional as $\hat{\beta}$ evaluation function (according non-strict and strict convexity).

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ALGORITHMIC PROCEDURES OF SYNTHESIS OF ROBUST-OPTIMAL CONTROL SYSTEMS FOR NON-LINEAR MOVING OBJECTS

Annotation. Approach to robust-optimal control system`s synthesis for moving objects, based on the optimization of nonlinear object`s trajectories and on control`s functions forming in the feedback structure, are submitted. Robust correction loop for robust correction under uncertainty conditions was constructed using a reference (optimal) model.

Key words: robust-optimal control, nonlinear model, moving object, system with variable feedback structure.

Formulation of the problem

Providing motion along the optimal stabilization trajectories for moving objects of various types in uncertainty conditions with considering functional limitations requires improvement and practical implementation of the robust-optimal control principles, which provide solution of relevant functional tasks in real time [1].

The dynamic of moving objects is described by multidimensional nonlinear models and it functions in conditions of insufficient priori information about the parameters of the object, under the action of uncontrolled random external disturbances and parametric noise of measurements. Requirements for maximum operating speed and accuracy of control for moving objects are determined by the need to provide the specified quality indicators of the working process and safe functioning in critical conditions.

Effective approaches for solving problems of robust-optimal control of moving objects, that use the fundamental properties of feedback [2], lead to static solutions which are not always provide the required control`s indicators quality. A wide application of PID - regulators for controlling moving objects has certain disadvantages: significant complexity of adjusting the regulator parameters as the number of controlled variables increases; high level of energy consumption; sensitivity to the influence of parametric noise and a range of others disadvantages.

One of the possible directions for creating effective structures and algorithms for robust-optimal control is the usage of the systems with variable feedbacks. Therefore, the task is to develop automated algorithmic procedures of synthesis for such systems with a given dimension of objects models, various types of boundary conditions and stabilization trajectories, taking into account restrictions on control actions. The optimal criterion specifies the requirement of the minimum time T of the transition process. Invariance of the system to incomplete informativeness of the model should be provided with contours of a robust correction, with minimum values of errors and their derivatives.

Material and methods of the research

The implementation of high-tech functional requirements for maneuvering and positioning of moving objects can be realized using application control systems with variable structure based on special switching feedbacks. Robust-optimal control assumes an optimal control system as a reference model, formed on the basis of priori information about the parameters of the object and controlled (measured) disturbances. Robust control can compensate the deviation of the current trajectory of a physical object from the optimal trajectory, which arises from a mismatch between the parameters of the model and the physical object and from influence of uncontrolled disturbances.

The proposed approach [3] includes the following main stages: optimal trajectory planning; synthesis of control functions and determination of the moments of their switching in corresponding feedback circuits of *n*-dimensional moving object that has the form

$$\dot{\mathbf{X}}(t) = \mathbf{A}_{\mathbf{X}}\mathbf{X}(t) + \mathbf{B}_{\mathbf{X}}\mathbf{U}(t),$$

where $\mathbf{X}(t)$ – vector of controlled coordinates $n \times 1$; $\mathbf{U}(t)$ – control vector $n \times 1$; $\mathbf{A}_{\mathbf{X}}, \mathbf{B}_{\mathbf{X}}$ – matrices of nonlinear parameters $n \times n$.

Planning the trajectory of a non-linear dynamic object consists of determining the required number of trajectory segments with constant values of the corresponding derivatives of the state coordinates and switching time moments of control`s functions in the feedback circuits during the transition from the initial segment to the specified segment of the trajectory. Switching of control functions changes structural configuration of feedbacks and solves the problem of providing optimal trajectory of the object with required order of derivative of the state coordinate, and with the corresponding positive or negative constant value.

Synthesis of control functions are determined on the basis of equations for the corresponding force`s (moment`s) balance and their derivatives, under which the conditions of constancy of the corresponding derivative of state coordinate vector are satisfied on certain segments of trajectory. For example, for a constant derivative of the third order $\dddot{\mathbf{X}}_c$, the vector-matrix equation of control has the form

$$\mathbf{B}_{\mathbf{X}}\ddot{\mathbf{U}}(t) + (\mathbf{A}_{\mathbf{X}}\mathbf{B}_{\mathbf{X}} + 2\dot{\mathbf{B}}_{\mathbf{X}})\dot{\mathbf{U}}(t) + (\mathbf{A}_{\mathbf{X}}^2\mathbf{B}_{\mathbf{X}} + 2\dot{\mathbf{A}}_{\mathbf{X}}\mathbf{B}_{\mathbf{X}} + \mathbf{A}_{\mathbf{X}}\dot{\mathbf{B}}_{\mathbf{X}} + \ddot{\mathbf{B}}_{\mathbf{X}})\mathbf{U}(t) =$$
$$= \dddot{\mathbf{X}}_c - (\mathbf{A}_{\mathbf{X}}^3 + 2\dot{\mathbf{A}}_{\mathbf{X}}\mathbf{A}_{\mathbf{X}} + \mathbf{A}_{\mathbf{X}}\dot{\mathbf{A}}_{\mathbf{X}} + \ddot{\mathbf{A}}_{\mathbf{X}})\mathbf{X}(t).$$

In this case, generalized conclusion can be done with respect to direct optimal conditions for constructing the trajectories of a moving object in coordinate form. The trajectory for a given boundary conditions will be optimal (in terms of speed) with maximum order of maximum values of the derivatives of the state coordinate vector, taking into account the constraints on the control action. In this case trajectory will be with maximum energy expenditure.

The multidimensionality of moving object`s models and the constraints on control actions determine the required number and values of derivatives of controlled coordinates, which considerably complicates the form and calculation of optimal trajectories. For a given boundary conditions and values of derivatives of an object`s coordinate vector, determined with allowance for constraints on the control, algorithms (based on solving algebraic equations systems) are created.

These algorithms include [3] the formation of a sequence of switching times of control functions in the feedbacks of the controlled object and if the system is multidimensional - usage of master, sub-master and slave variables.

Conclusions. Algorithmic procedures for automated synthesis of control functions for multidimensional nonlinear systems allow: solving optimization problems of stabilization processes for the maximum operating speed criterion; create software tools for automation synthesis of robust-optimal control systems for moving objects of various purposes, for example, the dynamic positioning of drilling vessels or drones for monitoring safety of navigation and environment in intensive navigation areas.

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OPTIMAL TRANSFERS BETWEEN NEARBY ELLIPTICAL ORBITS WITH TAKING INTO ACCOUNT SHADOW

Annotation. The jet acceleration optimal programs of orbital transfer vehicle with solar electric thrust system, which executes payload delivery between nearby elliptical orbits in near space, are built. Optimality criterion is the maximum payload mass. The influence of the Earth's shadow on the efficiency of the thrust system is analyzed.

Key words: orbital transfer vehicle, optimal transfer, electric jet thruster, shadow.

One of the most important problems of modern astronautics, is the development orbital transfer vehicles (OTV) able to provide efficient movement of cargos between near-earth orbits. To solve such problems it is necessary to create methods to determine the type, structure and interaction of elements of the thrust system (TS) of OTV, which provide realization of planed mission in the best way. That, in turn, leads to the need for joint optimization of transfer trajectories and thrust system modules parameters and ways to control. The need to find controls, trajectories and TS parameters in solving a joint optimization problem due to the influence of TS parameters on the its mass, size of the set of admissible controls, and therefore, choice of trajectory.

Due to the extremely high cost of orbiting mass unit, significant importance is the question of maximizing payload weight percent in the initial weight of the OTV, and thus, to put the mission was feasible.

The most effective among current and future jet engines with a current efficiency of spending working substance to generate thrust are electric propulsion engines (EP). Their using can significantly increase the mass of the payload, or if the payload mass is given significantly reduce the mass of the working substance in comparison with the case using traditional chemical engines of large thrust. Despite the fact that the best examples of current and future nuclear reactors whose characteristics exceed solar battery (SB), through consideration of environmental safety exactly the SB remain the main source of energy for electric propulsion power when maneuvering in near-Earth space.

Classical solar electric thrust TS consists of two main components: the SB and the EP. One of the major negative factors affecting the operation of this TS is the inability operation while the OTV is in the shadow of the Earth, leading to the presence of forced passive arc trajectory of interorbital transfers.

The problem of optimization controls, trajectories and OTV parameters which performing the maneuver of small changes of osculating elliptical orbit parameters within one revolution around the center of gravity in the central Newtonian gravitational field. The purpose of optimization is a maximum payload mass. The motion of OTV is modeling by motion of a particle of variable mass. OTV initial mass consists of the mass of SB (source of energy), the electric propulsion mass, the mass of the working substance of EP and the payload mass. We consider that points entry into the shadow and out of the shadow are set. Optimization of controls is made using Pontryagin maximum principle. Linearized equations of motion are integrated in elementary functions. The analytical expressions for optimal masses of OTV units are obtained. Influence of the duration and location of the shadow arc of trajectory on deterioration of problem quality criterion is estimated. Found that increasing the length of the shadow arch leads to the decreasing of payload mass. The most negative impact shadow observed in the case when in the shadow zone fall trajectory arcs with relatively large value module of vector of desired reactive acceleration (jet acceleration, which is preferably implemented at the absence of shadow).

UDC 629.7.05

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SYNTHESIS OF ALGORITHMS FOR ATTITUDE CONTROL OF A SPACERAFT BASED ON GENERALIZATIONS OF LYAPUNOV DIRECT METHOD

Annotation. Well-known generalizations of the direct Lyapunov method to the study of the stability of invariant sets of dynamical systems are applied to solving the problem of synthesis of attitude control of space vehicles. Generalizations of the existing algorithms for attitude control and stabilization of a spacecraft relative to the inertial coordinate system (ISC) are obtained. New algorithms for attitude control and stabilization of a spacecraft relative to the rotating (orbital) SC are proposed.

Key words: spacecraft, attitude control, stability of invariant sets, control algorithms.

The tasks of improving control systems for orientation and stabilization of spacecrafts are of utmost topicality for space technology since its origination. Constantly increasing functional content and complexity of tasks solved by up-to-date spacecrafts result in more strict requirements to the quality of the processes of their orientation control. For example, obtaining images with high resolution and accuracy of geo-referencing in problems of remote sensing of the Earth is directly related to the increase of orientation accuracy. The greatest potential in the implementation of these requirements belongs to control systems, whose software uses methods and algorithms for attitude control based on the use of quaternions. It is the development and improvement of such algorithms that is the point of numerous studies with results reflected in many modern publications. However, papers devoted to problems of stability investigation and synthesis of attitude control algorithms cover vaguely or completely do not cover the features of systems of differential equations of angular motion of spacecraft's with the state vector made up of the components of quaternions or, more specifically, the Rodrig-Hamilton parameters. These systems of equations have a motion integral - the norm of the state vector is identically equal to one. In addition, the same spacecraft orientation geometrically corresponds to two values of the state vector or quaternion components. Therefore, no solution of such a system can be asymptotically stable in the sense of the corresponding classical mathematical definitions of this concept or property. The inherent property of such systems correlates with the definition of conditional asymptotic stability or stability on manifolds.

This report is devoted to the partial elimination of the discussed remarks.

A mathematical model for the controlled process of angular motion of a spacecraft is proposed, where the evolution of its kinematic variables is described by nonlinear differential equations with a phase state vector in quaternion components. The proposed model describes the orientation of a spacecraft as relative to both the orbital coordinate system (OCS), and the inertial one (ICS). To synthesize control algorithms, the model uses well-known generalizations of Lyapunov's direct method of studying the stability of individual solutions of systems of equations to the study of the stability of invariant sets of such systems. Specific types of Lyapunov's functions positively defined with respect to these sets are proposed.

The existing algorithms for attitude control of a spacecraft relative to the ICS are generalized from the case of combining the associated coordinate system (SCS) to the case of its arbitrary assignment. New algorithms for achieving arbitrary spacecraft orientation and its stabilization with respect to OCS are proposed.

A computer simulation of the dynamics of spacecraft orientation processes was performed using the proposed algorithms. A series of computational experiments has illustrated their effectiveness.

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DETERMINATION OF THE PARAMETERS OF THE ANGULAR MOTION OF THE SPACECRAFT FROM THE INFORMATION OF THE STAR SENSOR USING THE DYNAMIC EQUATION IN THE RODRIG-HAMILTON PARAMETERS

Annotation. The problems of constructing algorithms for determining the parameters of the rotational motion of a spacecraft from the information of a star sensor are considered, using the dynamic equation of motion in the Rodrig-Hamilton parameters. The results of modeling the work of the proposed algorithms are presented.

Key words: spacecraft, quaternion, star sensor.

In the report questions of definition of parameters of rotational movement of a spacecraft on the information of the star sensor are considered with the help of a dynamic filter. When constructing the filter, we used the model of the rotational motion of a spacecraft in the form of a dynamic equations of motion in the Rodrig-Hamilton parameters [1].

Formulation of the problem

Let the rotational motion of a spacecraft relative to an inertial coordinate system be described by a second-order differential equation in the Rodrig-Hamilton parameters

$$\ddot{\Lambda} = (I_4 - \Lambda \cdot \Lambda^T) \cdot U - \Lambda \cdot \left\| \dot{\Lambda} \right\|^2 . \quad (1)$$

In equation (1), the vector $U \in R^4$ is related to the instant of control $M_u \in R^3$ of the dependence

$$U = \frac{1}{2} A^T(\Lambda)^{-1} \cdot \left[M_u - \omega \times J\omega \right],$$
$$A(\Lambda) = \left[-\lambda \quad \lambda_0 I_3 - \Phi(\lambda) \right].$$

On board the spacecraft there is a star sensor, which at time points t_k gives the quaternion Λ of the transition from the inertial coordinate system to the associated coordinate system. It is necessary to find the dynamic filter equation for obtaining estimates $\hat{\Lambda}, \hat{\dot{\Lambda}}$ on the output information of the star sensor $y = \Lambda$.

Results. For equation (1), from the measurement $y = \Lambda$, the equations of the dynamic filter are obtained in the form of a linear observer with constant coefficients and the results of numerical simulation are presented.

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UDC 004.8

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THE FEATURES OF INTELLEGENT COMPUTER

Annotation. The architecture shortcomings of the up-to-date computer systems and the essential features of artificial intelligence systems are discussed. The practicality of building the structure of the knowledge system and the architecture of the computer system on the basis of the ideal structure of scientific theory is demonstrated. The structure of the functionally complete core of the intellectual computer is shown. It consists of the knowledge database, the knowledge database translator, the knowledge database interpreter, the terminal interpreter, the dictionary of concepts and two data arrays. It is demonstrated that this architecture provides the interpreting-translating process as well as the translating-translating process of setting and solving an arbitrary problem.

Key words: computer system, artificial intelligence, knowledge processing system, structure of scientific theory.

Architectures of modern computer systems have the traditional flaws: the wide semantic gap between programming languages and human languages for description of problems both in science and in practice; there also exists the wide semantic gap between the scientific and practical approach to problem solving and programming technology; the relatively low rate of reusing application software etc. Overcoming these flaws massively depends on the success of the artificial intelligence (AI) studies, the different models of intelligent computers architectures and systems architectures are proposed.

Using the generally accepted principles, let us formulate the features of the intelligent computer required for building artificial intelligent systems.

A computer is considered intelligent when a human expert by results of communication cannot distinguish the computer from a human being. Such a computer should have the following tools:

- tools for natural spoken language processing in the capacity sufficient for successful communication let’s say in English;
- knowledge representation tools, using which it would be able to store what it learns or reads;
- the tools for automatically formulating logical conclusions in the process of using the stored data to find answers to the questions and log the results;
- machine learning tools, which allow it to adapt to new circumstances and to identify and extrapolate the features of typical situations;

In order to pass the complete Turing test it is also considered necessary for the computer to have the following:

- machine vision tools for object identification;
- robotics tools for manipulating and moving objects.

The theory development and the creation of artificial intelligence systems is linked to the problem of organizing the knowledge of the world in the form of structures, which depict real relations between the objects and real events. Knowledge processing is one of the areas of practical application of AI, which implies the use of human knowledge by the computer in solving real-world problems.

The most fundamental and important problem of knowledge processing systems – the description of the content and the form of knowledge of any theory that guarantees precise results by the conversional rules, which correspond to natural human abilities and experience and allow for effective computer realization.

The research of the theory structure is traditionally limited by it’s semantic. In the structure of semantic of scientific theory a distinction suggested [1]: the conceptual model (theoretical schema) – the unified system of definitions of theory terms with interconnections and dependencies; the empirical model is the system of the operational definitions of basic terms of the conceptual model on the whole set of the objects of the studied part of reality; the core of the theory is the structure of the using of axiom system of the theory in the logging process of the conceptual model of the task in the signature of the conceptual model of the theory; the theory-effect forms the set of mutually independent subsidiary sub-systems, each of them creates a special section of the theory, has its own laws and the abstract object (like the output theory has), this sub-system is created for the purpose of solving a specific problem by providing the transition from the fundamental laws of reality to their specific form; the results of the theory are the truths derived when using the theory for solving the current problems.

Any scientific theory is available for use and development though its language and any language is inherent a certain theory. Thus, the problem of the intellectual computer is narrowed down to the language problem and its implementation. In [2] the task of developing the new way of knowledge representation and usage is formulated and solved that is adequate to the process of solving the structurally complex tasks, according to which the final software product is comprised of two parts.

The first part (the knowledge database) is a hierarchical structure on the set of the concept definitions (non-terminals) linked by the basic relations of the meta-language of normal forms of knowledge, that is the development of the expressive abilities of the Extended Backus-Naur Form language.

The second part is comprised of the two sub-sets – the set of the elementary algorithms and the set of elementary data structures, which are implemented in one of the traditional programming languages in the form of a unified library system.

Accordingly, the structure of functionally complete core of the intelligent computer (Fig. 1) includes: the knowledge database, the knowledge database translator and interpreter, the interpreter of terminal programs, the dictionary of concepts and two arrays – of input and output data.

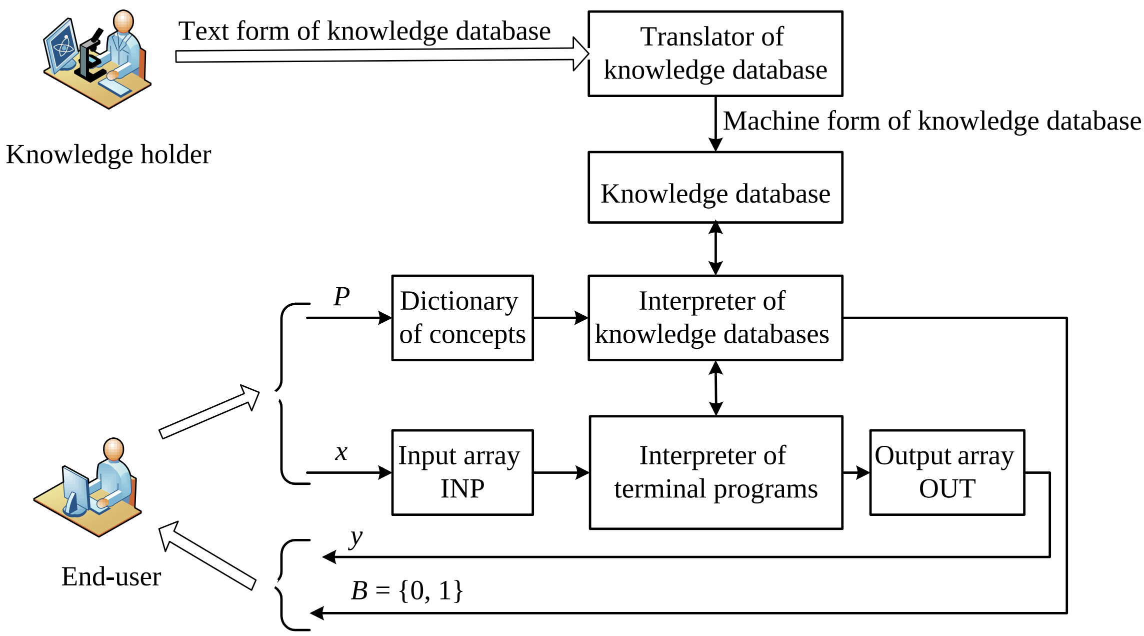

Figure 1 – Functionally complete core of the intelligent computer

The knowledge database translator converts the text representation of the knowledge database (KB) into machine form (KBS). The input and output arrays contain the following data: subject x of categorical statement $P(x)$, which is necessary to prove, and, accordingly, subject y, received as a result of its successful proof. The database interpreter performs the logging of the categorical statement $P(x)$ according to interpretation algorithm F_{INT}: $F_{INT}(x, P) \rightarrow y, B$, where $B = \{0, 1\}$ – the logical result of the truth logging $P(x)$,y – subject received as a result of success.

This architecture provides both the interpreting-translating process [3] and the translating-translating process of formulating and solving of an arbitrary problem.

Conclusions. The most significant characteristics of the intelligent computer is the meta-language with universal expressive abilities, its efficient implementation and modeling of all the functions of scientific theories.

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INTELLECTUAL SYSTEM OF OPTIMAL EVACUATION ROUTE SEARCHING

Annotation. The intellectual system of optimal fire evacuation route searching from shops and trading room in case of fire is considered

Key words: evacuation, optimal evacuation route.

Formulation of the problem

Let us consider a graphical representation of the object required for solving the problem of evacuation (Fig. 1). As an object a trading room (TR) that is located on one of the floors of multistorey shopping center (SC) is selected.

There are some shops, partitioned by drywall constructions that may be on both sides of TR (numbered from 1 to 18). Inside of TR may be outlets without walls, restaurants, cafes (marked with circles).

In floor of TR LED lights of different colors are mounted with certain discrete (marked by dots in the figure), which are switched at the time of the fire making evacuation route (light of one color combustion defines one possible route). Emergency exits from TR are identified (numbered from 1 to 8), and at the door of each store the input/output sensors are installed, which data is processed to determine the number of people in the store at each time point and transfer the data to the fire alarm control panel of SC. The number of people that are in the TR outside of stores can be determined only approximately. We associate a connected graph with this graphic model that is shown in Fig. 2, for which, the following initial data is determined:

1. $A = \{a_i\}, i = \overline{1, n}$ is the set of shops and retail outlets in the TR; each element a_i corresponds to a pair of $\{x_i, y_i\}, i = \overline{1, n}$ is the coordinates of locations of the shops;

2. $B = \{b_i\}, i = \overline{1, n}$ is the number of visitors who are currently in stores.

3. $C = \{c_k\}, k = \overline{1, m}$ is the set of exits from TR with coordinates $\{x_k, y_k\}, i = \overline{1, m}$.

4. $D = \{d_p\}, p = \overline{1, l}$ is the set of shops where there was a fire with coordinates$\{x_p, y_p\}, p = \overline{1, l}$.

5. $E = \{e_j\}, j = \overline{1, q}$is the set of points of fire in the TR with coordinates $\{x_j, y_j\}, j = \overline{1, q}$.

6. $F = \{f_h\}, h = \overline{1, v}$ is the set of LED lamps which are mounted in the floor of TR with coordinates $\{x_h, y_h\}, h = \overline{1, v}$.

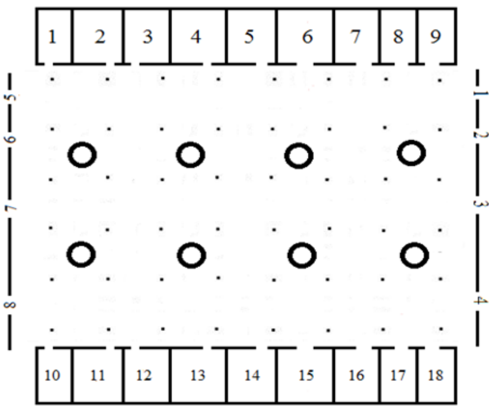

Figure 1 – A graphical representation of the object evacuation

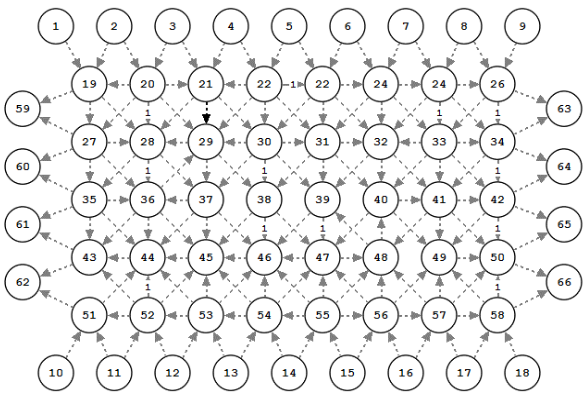

Figure 2 – The graph corresponding to the location of the highlight points of the evacuation routes

The vertices of graph are numbered from 1 to 66, each of them corresponds to a single element. Since the vertices 1–18 correspond to the set of shops, the vertices 19–58 correspond to the set of LED lamps, and the vertices 59–56 correspond to the set of exits.

The task of determining optimal routes for the evacuation of visitors from shops and TK in case of fire in one or more stores from the set one or more points of TR from the set Each of the routes should be highlighted with different colors, be of minimum length and provide the evacuation of maximum number of people in minimal time.

Algorithms of optimal routes for evacuation determination

For modelling shortest path routing problem using HNN, communication network is represented by N×N adjacency matrix which shows network connectivity where diagonal elements are removed. Each element in the matrix is represented by a neuron which is described by double indices (i, j) where the row subscript i and the column subscript j denote node numbers, and a neuron at location (i, j) is characterized by its output Y_{ij} that becomes 1 when the link from node i to node j is used in the path and 0 otherwise.

The network evolutes the internal activation to reduce the overall energy and neurons update their state where $\partial E / \partial Y$ is calculated directly and is summation of all energy terms. That is a discrete time-step approach for solving the differential Equation that describes the connection between changes in activation and energy terms.

Let us consider that there is a fire in the shop No.7 on the diagram (see Fig. 1). The number of people in the stores was 700, the number of people in the TR was 500.

According to the proposed algorithm and based on the work of the neural network evacuation routes (shown in Fig. 3) are defined.

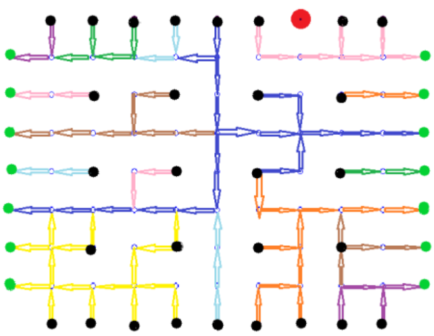

Figure 3 – The scheme of evacuation in case of fire in one of the shops

On the scheme, the red dot is the center of fire, black dots are the shops and retail outlets, green dots indicate locations of emergency exits. The evacuation routes for different stores and retail outlets are marked with the arrows of different colors.

On the scheme, the red dot is the center of fire, black dots are the shops and retail outlets, green dots indicate locations of emergency exits. The evacuation routes for different stores and retail outlets are marked with the arrows of different colors.

CONCLUSION

An algorithm for optimal evacuation that is based on use of graph theory and the optimization algorithms based on artificial neural network of Hopfield is developed.

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A NEW PHOTOVOLTAIC ETHANOL GAS NANOSENSORS

Introduction

Progress in gas sensors has made it possible to prepare novel gas sensitivity elements on the base of nanotechnology. However, modern ethanol gas sensors have the limited dynamic range of measurements. For example, dynamic range of measurements for environmental alcohol sensor of Dart Sensors Ltd is 0-250 ppm [1], MR513 Hot-wire type alcohol gas sensor 0-1000 ppm [2], TGS 2620 alcohol vapors sensor 50-5000 ppm [3]. A photovoltaic junction between nanoporous and crystalline silicon can be produced by electrochemical etching technology of a silicon wafer surface. We found a technology for producing a special gas and light transparent contact for new photovoltaic device. In this paper we report about gas sensitivity properties of these sensors for ethanol vapors.

Experimental

Porous silicon for this study was formed by anode electrochemical etching of (111) oriented p-type silicon wafer with a resistivity of 10 Q_{cm} at the current density of 10 mA/cm^2, in a HF-based solution. During the etching process an additional illumination and an ultrasonic processing was applied to the silicon surface. The thickness of porous silicon layers is found from cross-section scanning electron microscopy (approximately 12 um at 5 min etching time). Thin porous film from aluminum was manufactured on a surface of porous layer (gas and light transparent contact (C) on Fig. 1). This film was transparent to illumination and gas molecules and created electrical contact with porous silicon (electrical contact (A) on Fig. 1). Top (A) and bottom electrical contact B to silicon wafer is manufactured by standard technology (Fig. 1).

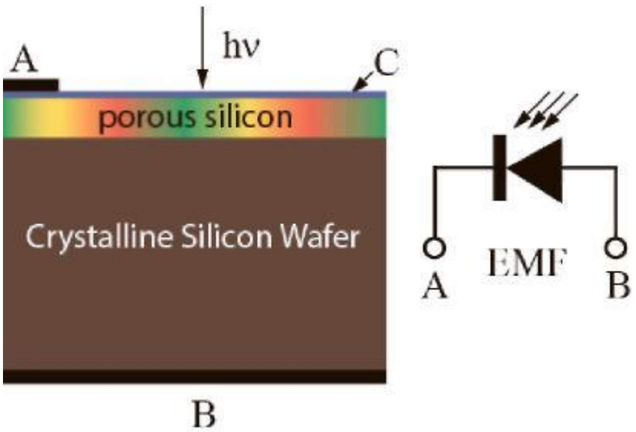

Figure 1 – A cross-section of photovoltaic sensor structure with nanoporous silicon on crystalline silicon wafer.

Manufactured porous silicon layer had red (W*780 nm) luminescence under laser illuminations at a wave length of 441.2 nm. This red luminescence had a half-width at half maximum of approximately 0.2 eV. The luminescence in visible range of spectrum is related to quantum wires. Broad band of luminescence peak demonstrates a different thickness of quantum wires. It means that porous silicon have quantum wires with greater band gap than crystalline silicon. Band gaps of our nanowires system are in the ranges of 1.7±0.2 eV. In our case the photovoltaic junction should be formed between porous silicon and silicon wafer. The electrical contacts had ohmic properties. The light induced heterojunction can be the single reason of occurrence of the photo electromotive force on contacts. Photo-EMF was observed near the wavelength of light of approximately 730 nm. An increase of ethanol concentration in the measurement camber leads to a decrease of the Photo-EMF magnitude.

Usually photo-detectors have a maximum photo-response at a wavelength of light corresponding to band gap energy. In our case the band gap energy of a porous silicon layer equals approximately 1.7 eV (energy of light quantum at wavelength 730 nm).

The photo electromotive forces between A and B contacts under illumination of samples were studied in a special measuring chamber at room temperature with different composition of nitrogen atmosphere and ethanol vapors.

Results and Discussion

Magnitudes of electrical voltages (Photo-EMF) between A and B contacts depended on concentration of ethanol vapors in the measurement chamber and intensity of illumination (Fig. 2).

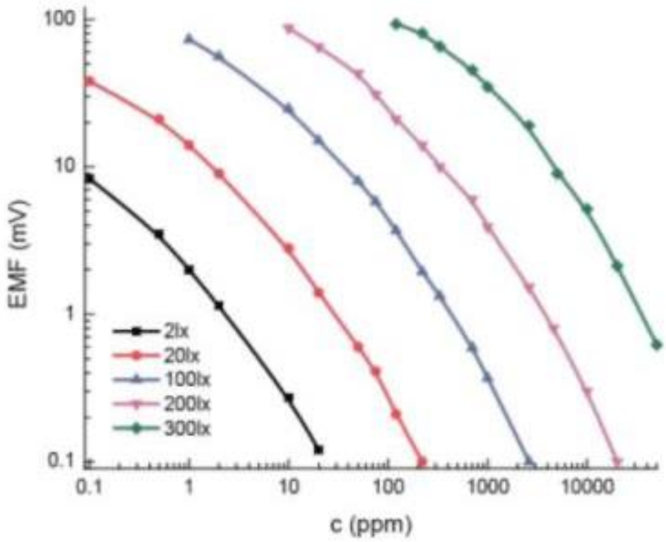

Figure 2 – Dependences of Photo-EMF on concentration of ethanol vapors under different illumination levels.

Different levels of Photo-EMF are detected for different ranges of concentration: from 10 ppm to 1000 ppm at 200 lx, from 1 ppm to 100 ppm at 20 lx and from 0.1 ppm to 10 ppm at 2 lx.

Illumination of porous silicon layer generate electron-hole pairs *G* in nanowire (generation process is marked in red in Fig. 3). These electron-hole pairs recombined through recombination centers (recombination process is marked in blue in Fig. 3). A part of holes reach to *p*-type region of crystalline silicon. Then photo electromotive force should appear on heterojunction.

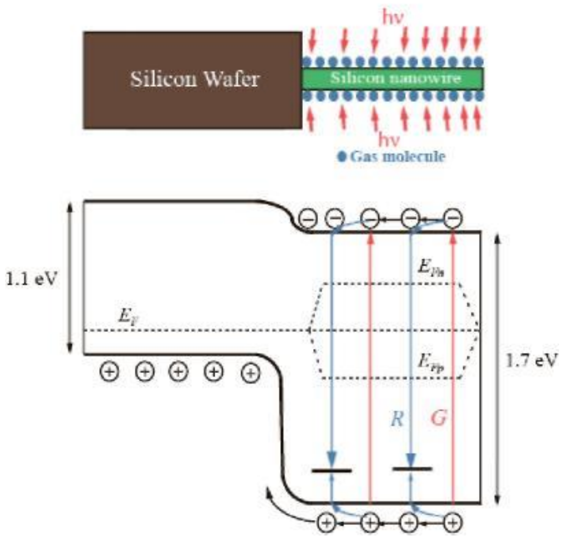

Figure 3 – A model of a new photovoltaic gas sensors and a mechanism of photo- and gas-sensitivity.

The intensity is inhomogeneous along nanowires. The generation of electron-hole pairs is maximal on top part of the porous layer. A physical mechanism of Photo-EMF should be identical with well-known photo electromotive force of light induced photovoltaic junction.

Ethanol molecules are adsorbed mainly on surface of nanowires (Fig. 3). Adsorption of ethanol molecules creates new surface levels. A re-charging of levels in quantum wires and electrical micro fields close to polar ethanol molecules can effect on recombination rates of electron-hole pairs. In our case, the ethanol adsorption substantially influences on magnitude of photo-EMF (Fig. 2).

Conclusions. Based on our results, we conclude that photo-EMF on photovoltaic junction between nanoporous and crystalline silicon depends on ethanol vapors concentration in wide range. In the literature on gas sensors technology (for example, [4]) there is no find information about similar sensors sensitivity. A use of the new photovoltaic gas nanosensors technology will open a new way of building the wide range gas sensors.

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THE CONTROL ALGORITHM OF THE INTELLIGENT ROBOTIC ELECTRICAL COMPLEX IN INDUSTRIAL GREENHOUSES

Annotation. Mobile robotic electrical complex, able to move the greenhouse area, using technology guides. This complex will provide monitoring of basic parameters of atmospheric greenhouse, Phytomonitoring, including product quality, identifying with her band. Management strategies Electrical complexes which provide cultivation technology will be formed taking into account the information received from the robotic complex electrical maximizing profit production at the moment. Such complex should have some signs of intelligence and work on specific control algorithms that will: assess the quality of products and fitostanu monitor the atmosphere, move to the area, minimizing the traversed path, avoid obstacles, and so on.

Key words: algorithm, microclimate, robotic systems, greenhouse.

To monitor the atmosphere in the buildings greenhouses used a mobile robotic electrical complex, shifting technological guides for measuring atmospheric greenhouse temperature, humidity, carbon dioxide concentration at different levels and temperature of the soil, plants, evaluates the quality of plant products, identifying with the area of greenhouse [1, 2]. The information transmitted to Web system forming higher level management strategies to ensure the adopted criteria optimization. Given the presence of zones of similarities such complex moves, minimizing the traversed path, bypassing obstacles. Videosensory recognize images and assess the quality of the fruit, leaf surface, which allows to predict the development of plants in general. This approach, when used as a feedback quality plant products offered for the first time and this, in our view, will maximize profit greenhouses.

The developed algorithm of intelligent robotic electrical industrial complex in the greenhouse, which includes:

– evaluation of product quality;
– fito state and monitoring of the atmosphere;
– move around space, minimizing the traversed path, avoiding obstacles;
– transfer received information into a strategy of control of a higher level.

Conclusions. The control algorithm of the intelligent robotic electrical complex in industrial greenhouses allows you to: assess the quality of products and fito state monitor the atmosphere, move to the area, minimizing the traversed path, avoid obstacles, transmit the information to the system management strategies forming higher level.

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THE METHODS OF GEOMETRICAL COMPLEX ANALYSIS IN THE PROBLEM OF THE PERIODICAL POINT

Annotation. A problem of finding of periodic points of nonlinear discrete systems is investigated. The algorithm of constructing coefficients semi linear generalization delayed feedback control is suggested. The examples that confirm effective the algorithm are considered.

Key words: nonlinear dynamic systems, delayed feedback control, cycles, chaos.

Various problems in engineering, physics, biology and in many other fields of knowledge are reducible to the problem of a periodical point. Our goal is to find the periodical point of chaotic systems. Assume that a vector recurrent equation $x_{n+1} = f(x_n), n = 0,1,\dots$ is given.

A periodic point is a generalization of the concept of a fixed point. The orbit of a point η_0 is the set $O(\eta_0) = \{\eta_0, f(\eta_0), f_2(\eta_0), \dots\}$, where $f_2(\eta_0) = f(f(\eta_0))$, $f_{T+1}(\eta_0) = f(f_T(\eta_0))$, $T = 2,3,\dots$. If $f(\eta_0) \neq \eta_0$, $f_\tau(\eta_0) \neq \eta_0$, $\tau < T$, $f_T(\eta_0) = \eta_0$, then η_0 is called T - periodic point of the map f. For the T - periodic point the set $O(\eta_0) = \{\eta_0, f(\eta_0), \dots, f_T(\eta_0)\} = \{\eta_1, \dots, \eta_T\}$ is called a periodic orbit.

Assume some eigenvalues of the Jacobi matrix $\prod_{j=1}^{T} f'(\eta_j)$ are outside of the central union disc $D = \{z \in C : |z| < 1\}$ in the complex plane. This eigenvalues are called multipliers and denote them as $\{\mu_1, \dots, \mu_m\}$. There are two basic methods to find the cycles: Newton-Raphson method and Average damping method. The disadvantage of Newton-Raphson methods is well known.

It is constructing a controllable iterative procedure defined by the recurrent relations

$$x_{n+1} = f(x_n, u_n),\ n = 0,1,\dots,$$

where the control u_n is a function of the values for the vector of recurrent sequence computed on the previous steps. This control u_n has to guarantee the convergence of the recurrent sequence to the cycle of the length *T*. That control is called the stabilizing control.

Particular case of the Average damping control is the Delayed Feedback Control (DFC).

Let’s consider the system

$$x_{n+1} = f(x_n) + u_n,\ n = 0,1,\dots.$$

There are different types of controls, such as linear [1], generalized linear [2], nonlinear [3], generalized nonlinear [4], semilinear [5], generalized semilinear [6], predicative [7].

All of these controls have the deficiency.

We suggest to use the convex combination of the generalized non-linear and semilinear controls

$$u_n = -(1-\gamma)\sum_{j=1}^{N}\varepsilon_j\left(f(x_{n-jT+T}) - f(x_{n-jT})\right) - \gamma\sum_{j=1}^{N}\delta_j\left(f(x_{n-jT+T}) - x_{n-jT+1}\right),\ \gamma \in [0,1].$$

In that case the recurrent equation takes the $x_{n+1} = (1-\gamma)\sum_{j=1}^{N} a_j f(x_{n-jT+T}) + \gamma\sum_{j=1}^{N} b_j x_{n-jT+1}$.

Sometimes it is more convenient to use the system $x_{n+1} = (1-\gamma) f\left(\sum_{j=1}^{N} a_j x_{n-jT+T}\right) + \gamma\sum_{j=1}^{N} b_j x_{n-jT+1}$.

Note that on a cycle of the length T the close-loop system coincides with the initial system.

Assume that we know the estimate of the set of the localization of the multipliers $M = \{\mu_1, \ldots, \mu_m\}$.

It is required to construct non-negative coefficients $a_1, \ldots, a_N, b_1, \ldots, b_N, \gamma$ in such way that T-cycle of the system $x_{n+1} = (1-\gamma) f\left(\sum_{j=1}^{N} a_j x_{n-jT+T}\right) + \gamma\sum_{j=1}^{N} b_j x_{n-jT+1}$ will be locally asymptotically stable. At that time that value N, that determines the length of the used prehistory should be as small as possible.

Using ideas of E. Landau, L. Bieberbach, L. Feier, T. Suffridg, S. Ruscheweyh we have formulized an algorithm of computing this coefficients with considering of minimal length of the prehistory, which is defined by value of *N*. As examples we detect cycles with length from 20 and more for such famous systems as Lozi map, Ikeda map, Henon map, Cubic Holmes map, Elhadge-Shprott map etc.

A problem of nowadays is to optimize our algorithm for finding cycles with larger lengths of discrete vector systems for an acceptable time.

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MODELING OF THE AUTOMATED CONTROL SYSTEM OF HEATING IN THE "SMART HOUSE"

Summary. The oscillatory mode of the "smart house" heating system with sensors for the presence of people, temperature and time of day was investigated. The decision to turn on/off the heating is taken by the fuzzy controller. Simulation showed the possibility of loss of stability of the control system. To analyze the stability of self-oscillations, it is proposed to use harmonic linearization.

Keywords: oscillatory regime, relay system, fuzzy control.

The problem of creation of control systems with elements of artificial intelligence (AI), which realize the control function with given characteristics of stability and quality is becoming more urgent. The paper deals with the problem of fuzzy control of a thermal object. The heating system of the "smart house" is considered as a thermal object. The solution of problems of fuzzy control is considered in many papers, in particular in [1]. In [2] the method for estimating the uncertainty of such control is considered, and in [3] – a technique for studying the stability of oscillations. However, in the study of fuzzy control of the oscillatory regime, a number of unsolved problems arise.

The aim of the work is to develop a model of a fuzzy control system for a thermal object and a methodology for studying the stability of the system.

With a fuzzy algorithm of control the calculation of the optimal average temperature, the deflection and the determination of the switch-on/off time of the heater is performed by the fuzzy controller (FC). The structural scheme of a fuzzy temperature control system is shown in Fig. 1. On the diagram: FCs - Fuzzy Sugeno conclusion; FC_3 – Fuzzy calculator Zadeh; *H* – heater; (r_1 – r_3) – rooms; (m_1 – m_3) – signals of moving sensors; ($t_{10} - t_{30}$) – preset room temperatures; y - average temperature in the rooms; *T* – time of a day.

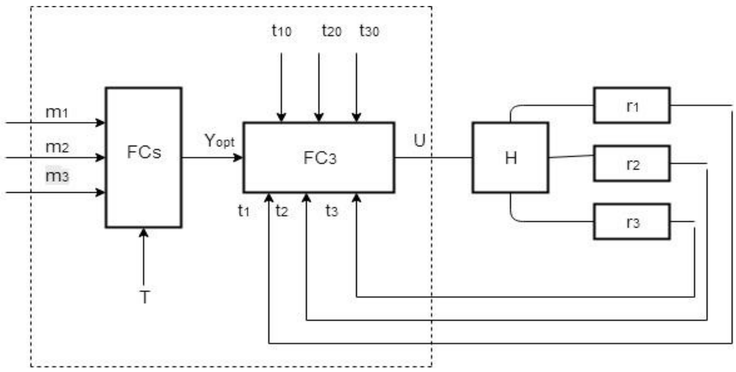

Figure 1 – Structural diagram of the SC heating with fuzzy controller

The process model is represented by a system of equations

$$\begin{cases} \dfrac{dt}{d\tau} = \lambda_н (t_н - t) - \lambda_п (t - t_0) \\ \dfrac{dt_н}{d\tau} = \lambda_в (t_в - t_н) - \lambda_н (t_н - t_0) \end{cases}, \quad (1)$$

where t – temperature in the room; $t_н$ – heater's temperature; $\lambda_н$ – heat-transfer coefficient of the heating element; t_0 – ambient temperature; $\lambda_п$ – loss factor due to a heat transfer to the external environment; $t_в$ – temperature of the heater in the first circuit of the boiler; $\lambda_в$ – heat transfer coefficient of the boiler, which reduces to a second-order equation. The oscillatory process of maintaining the temperature in the steady state is shown in Fig. 2. The oscillations are caused by the inertia of the object and hysteresis. The errors of the temperature sensors and the uncertainty in the operation of the sensors of the presence of people in the rooms lead to an uncertainty of the switching times of the heating/cooling.

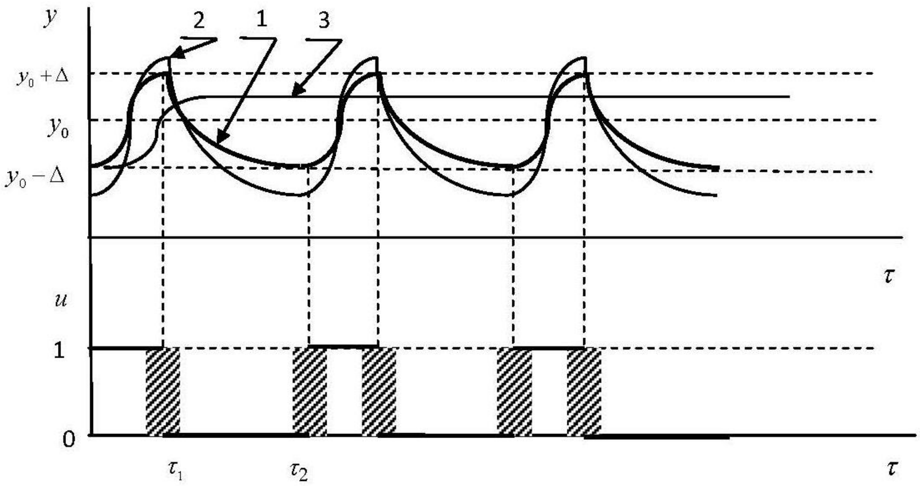

Figure 2 – Stationary processes of temperature variation

Simulation of system using the SciLab package showed the possibility of the appearance of unstable self-oscillations (2 and 3 in Fig. 2). Mode 2 condition: $\frac{dt}{d\tau}=0$. To study the conditions for the mode 3 harmonic linearization is used. The instability condition:

$$\frac{1}{\tau_1+\tau_2}\left[\int_0^{\tau_1} t_1(\tau)\sin\left(\frac{2\pi}{\tau_1+\tau_2}\tau\right)d\tau+\int_0^{\tau_2} t_2(\tau)\sin\left(\frac{2\pi}{\tau_1+\tau_2}\tau\right)d\tau\right]>\Delta,$$

where $t_1(\tau)$ – solution of the equations system (1) on the interval $(0,\tau_1)$, $t_2(\tau)$ – solution on the interval $(0,\tau_2)$.

Conclusions. The research of developed model of a fuzzy control system of a thermal object with the example of a "smart house" showed the possibility of the instability of the system. A method for the stability research of a fuzzy control system based on the harmonic linearization of an autooscillatory process and estimating a fuzzy dispersion is proposed.

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UNIFIED NATIONAL SYNCHRO-INFORMATION SYSTEM − HIGH-TECH INFRASTRUCTURE FOR AUTOMATED COMPLEXES

Annotation. Implementation of the proposed idea as a set of innovative tools that will work as part of the Unified National Synchro-Information System of Ukraine from the national time-scale reference sources is a real alternative to using foreign satellite navigation systems. The system will allow, due to the diversification of the digital transmission of clock signals, to provide information survivability and improve reliability.

Key words: automatic, info-communication, synchronization, system,synchro-information.

The rapid development of modern information technologies is characterized by the intensive use of reference values of the time and frequency for synchronous functioning of high-tech systems in the areas of defense, government cyber security and many other industries of Ukraine.

In Ukraine, there is a public service of reference time and reference frequencies that includes SE "Ukrmetrteststandard", that performs cross-regional and cross-industry coordination and execution of works aimed at ensuring the uniformity of time and frequency measurements [1]. Nowadays, the government service, despite generating and maintaining the national time scale at the level of the best world national scales, almost does not transmit the reference signals of time scale and frequency to the consumers by means of existing information channels. The existing technical means in Ukraine do not form a unified system and cannot satisfy the requirements of all consumers of time-frequency information. This encourages consumers to use synchronization information from other states and governments (for instance, from satellite navigation systems GPS and GLONASS), which creates a threat to national security and increases the risks of losing the uniformity of time and frequency measurements within the state. The main disadvantages of such satellite systems are dependence of their signal quality from non-deterministic characteristics of the open environment where radio waves are transmitted and, as well, the lack of protection against the intentional distortion of synchro-information.

Unified National Synchro-Information System of Ukraine (UNSIS) should serve to implement the processes of transporting information about a unified precise time, reference clock, time intervals so on for objects that need it (within the borders of the country) in order to ensure their coordinated, synchronous work [1-3]. With the implementation of the proposed idea, the conditions will be created for the information security of critical infrastructure facilities in the country and also practical results of dual use for government institutions will be obtained: The Armed Forces of Ukraine, GW "Derzhspeczv'yazok", SE "Ukrmetrteststandard" and others. Considering the above, it can be concluded that the issue of creating the UNSIS of Ukraine is of current importance.

Separately, the importance of obtaining reference time signals by special purpose services that solve the tasks of national cybersecurity of the government must be noted as well as the need to introduce a single (Kyiv) accounting and reporting time in the country.

The listed facts are weighty arguments for the need of creating UNSIS of Ukraine at the national scale.

Pointed necessity, importance and possibility of distributing quality synchro-information demand determining the priority of a mentioned innovative high-tech development direction and justification of the conceptual provisions of the construction of UNSIS of Ukraine taking into account the results of the research and deploying into production and operation of complex of domestic equipment for synchronization of telecommunication networks and information structures, which is competitive with the best world counterparts.

The proposed set of innovative tools will not only provide high-quality reference signals of united reference time but will also create conditions for effective synchro-information supply for other infrastructure facilities in the country with the minimal cost and will have practical results for dual use in The Armed Forces of Ukraine, improving government cyber security, due to building the UNSIS of Ukraine − modern autonomous land-based system, independent from foreign services of time and frequency.

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THE MODEL FOR DISTRIBUTED SYSTEMS TESTING BASED ON THE CONTROL SERVICES

Annotation. The paper presents a model for testing a distributed system that describes the process of testing services with its architecture and parameters. The controls services are used for testing that allow perform the testing process without disrupting the integrity of the system.

Key words: distributed system, control, testing services.

In order to perform the testing of distributed systems, there are used the methods that may violate the integrity both the system as a whole and the certain service. It is advisable to perform the testing that will not affect the operation of the distributed system in order to maintain the integrity of the system [1–3]. Therefore, we need to develop a model for testing of the distributed systems using the access control services.

Let a set X is a distributed data processing system that includes subsets $X_1, \ldots, X_n$. Each subset has a certain set of parameters $X_i = \{x_i^1, \ldots x_i^k\}$. The list of possible parameters here is: configuration, authorization algorithm, database, encryption algorithms, etc.

The subsets $X_1, \ldots, X_n$are communicating with each by a set of relationships Y, which includes subsets $Y_1, \ldots, Y_m$. Links *Y* are implemented as the main REST methods for communication between subsystems: GET, POST, PUT, DELETE, and the like. Each link has a specific set of parameter parameters $Y_i = \{y_{ij}^1, \ldots y_{ij}^s\}$, where i and j are the corresponding nodes of the distributed system. The list of possible parameters here is: transmission protocol, authorization parameters, request type, address, port, etc.

It is required to check the correctness of the request from the sender's node in order to ensure testing, and also to check the correctness of its reception by the receiver-node. To do this, we use the mechanism based on the add-in tools to the distributed system, i.e. the control service.

Let Z is the set of all control services, includes subsets $Z_1, \ldots, Z_q$. Each subset of control services has a specific set of parameters $Z_i = \{z_{ij}^1, \ldots z_{ij}^a\}$, where i and j are the corresponding nodes of the distributed system where the control services are applied.

The control service operates in two modes: the consumer and the supplier (Fig. 1). In the consumer mode, the request from the node of the distributed system is checked and the response is sent, and in the supplier mode – a request is made to the node of the distributed system and the response is checked.

The processing of the received and sent data is managed with a contract. The contract is a file in the *json*-format that contains the data about the address, service port and an array of control services.

The testing process in the consumer mode consists of the following iterations:

1. A node X_i sends a request via channel Y_i, that is forwarded to the control service Z_k.
2. Service control Z_k compares the expected query parameters with the real ones.
3. In case if the expected and the real request are identical, the control service returns the expected response to the node X_i, otherwise, the service returns to the consumer the status code with the error information.
4. The test is considered to be successful if the response that the control service was returned is equal to the expected response.

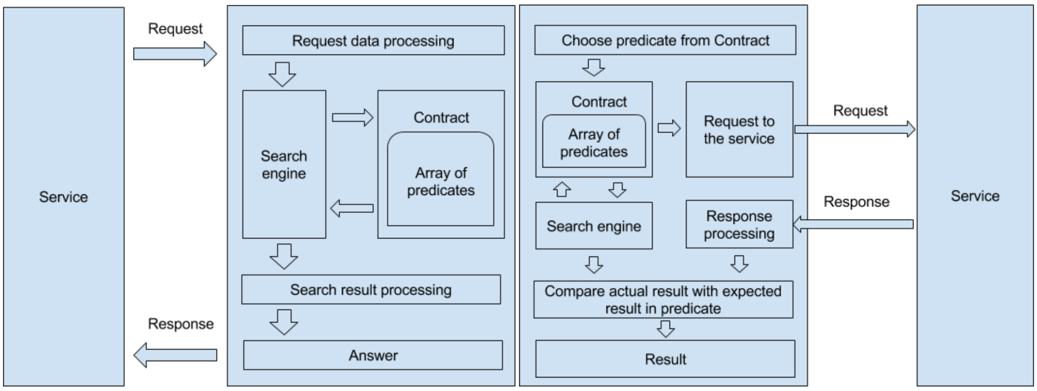

Figure 1 – The algorithm of functions of the nodes service control in consumer mode (on the left) and supplier (on the right)

The testing process in supplier mode consists of the following iterations:

1. The test code processes the expected query parameters that the control service Z_k contains and sends this request via channel Y_j to the node X_j.
2. The node X_j processes the request according to its functionality and sends a response to the service Z_k.
3. The test is considered to be successful in case if the answer is the same as the expected parameters of the answers in the service Z_k.

LetM_{ij} is the result of testing of the request from the customer service to the supplier's service.

Then:

$$M_{ij} = X_i + X_j + Y_m - Z_k. \quad (1)$$

The test will be successful in case:

$$f(M_{ij}) = 0. \quad (2)$$

The successful overall result of testing a distributed system:

$$f(M_{total}) = \sum_{i=1}^{n} \sum_{j=1}^{m} f(M_{ij}) = 0. \quad (3)$$

Conclusions. In this paper we suggested the model for testing of the distributed systems based on control services. This model allows to support the integrity of the distributed system and to correct the errors related to update of the system nodes software.

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THE DEVELOPMENT OF HIGHLY RELIABLE SOFTWARE SYSTEMS

Annotation. The application of insertion modeling technology to the development of highly reliable software components of software critical systems is considered.

Key words: theory of interaction, insertion modeling, cyber-physical systems, verification, testing

Insertion modeling technology [1] is based on the algebraic theory of interaction in multi agent distributed environments. We shall consider the application of this technology to create highly reliable software systems. High reliability requirements primarily relate to safety-critical systems. These systems especially include systems from aerospace and medical industry, nuclear energy and weapons production. Failures in these systems associated with the threat of life, loss of equipment, environmental destruction and so on. The process of developing highly reliable systems based on risk reduction or complete elimination of the violation of safety conditions in the system functioning. Safety critical systems include the modern cyber physical systems [2], which deeply integrate cyber (that is software) and physical (technical) components.

Software engineering of safety critical systems is based on the inclusion of verification and validation in the development process. Current methods require the use of formal verification methods for constructing mathematical models and generate test kits that provide maximum coverage program codes.

Reliability can be external and internal. External one protects against unauthorized interference, internal provides the absence of errors, the reliability and validity of internal interactions. Here we confine to the consideration of internal reliability.

Design and analysis of complex systems requires construction of formal models of different levels of abstraction at all stages of design and development. The use of formal models can detect incorrect decision error and impropriety in the early stages of development, which significantly reduces effort and saves money if these errors are detected in the later stages or in the resulting product.

In the insertion models a system is represented as a composition of environment and agents inserted into it. Environments and agents are represented as transition (dynamic) systems that evolve over time and have externally observable behavior. The behavior of agents and environments determined using equations in behavior algebra. Behavior algebra is continuous multisorted algebra and insertion of agent into environment changes the environment behavior through continuous operator. Continuity is understood relatively to complete partial order topology defined for the behavior algebra.

The main method of investigation of insertion models is a symbolic modeling of attribute environments. The states of such environments in symbolic modeling are predicate calculus formulas with quantifiers and software implementation of these models use symbolic system of automatic deduction.

Fundamentals of insertion modeling were laid in the late 90's in the works on the model of interaction between agents and environments, and practical use of insertion modeling refers to the early 2000s, when on the order of Motorola in the Ukrainian company ISS with the staff of Glushkov Institute of Cybernetics a system VRS for automatic verification of software systems requirements has been developed. Later the system was acquired by the American company UniqueSoft. On the basis of verification system new development and design tools has been developed, including means for testing and code generation.

Experience gained in working with foreign companies was used to develop the Institute of Cybernetics own insertion modeling system IMS, which has the means to create highly reliable software systems. In the developing of this system, fellow workers from Kherson State University are actively involved. IMS tools include tools for symbolic verification, test generation with almost 100% coverage of code, tools for program invariants generation, means of optimizing transformations, and refactoring of programs and their models. An important area of application of this technology is the parallelization of computational processes on multiprocessor computers and organization of high performance computing in network and cloud systems.

Source language of IMS consists of algebraic and logical means of describing the behavior of systems in conjunction with graphic languages MSC and UCM, belonging to ITU standards. The formal semantics of the language is presented using insertion models. It is used in the process of developing of IMS, providing high quality products.

The next goal of the development of insertion modeling is to adapt insertion models for the development of cyber physical systems. Currently the main mathematical models in this area are timed and hybrid automata. Now we developed a new model which generalize old models and is consistent with insertion models. This model is a semigroup transition system. The elements of semigroup of traces are used as actions and all transitions are equipped by duration – a number from the additive subsemigroup of semigroup of real numbers. Agents and environments are semigroup transition systems and attribute environment represents the evolution of physical components as well as the data structures of software components.

Now the tools for modeling, verification, and testing of insertion models of cyber physical systems are developing.

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THE MASTER'S PROGRAM "DATA SCIENCE"

Annotation. Consider feasibility of doing a new master's program "Data science" for Masters enrolled in the specialty "Computer Science". The basic directions of training programs presented.

Key words: information systems, mining, OLAP, Data Mining, big data.

Formulation of the problem. In 2006, the NULES of Ukraine began bachelors on specialty "Information Control Systems and Technologies", which after a short time was called "Computer Science". At present undergraduates who study in this field, have the opportunity to acquire knowledge of the program "Data Science". From driving a new master's program there are some problems: why such a program name and how it relates to the same degree; or demanded experts with relevant knowledge; which subjects are taught within the program.

Essence of research. Explore communication computer science from the data science. The term "computer science" (in French "Information") emerged in the 60s. In France for the title field that is associated with processing information via computers (PC), and was created by merging the two words "information" and "automatic". Information technology, which is directly related and specialty "Computer science" involved in the creation, development and operation of information systems. Because information technology began to develop rapidly since the 1960s, with the emergence and development of early information systems (IS). The development of the Internet as well as investments in infrastructure and services caused the rapid growth of IT industry in the late 1990s [1]. The data science - section of informatics, which studies the problems of analysis, processing and presentation of data in digital form. Combines techniques of data in large volumes and high levels of parallelism, statistical methods, methods of data mining and artificial intelligence applications to work with data and methods of designing and developing database [2]. The beginning of the formation of the subjects considered in 1966, when it was founded by the Committee on Data for Science and Technology (CODATA), and the first entry period relating to 1974 in a book by Peter Naur, in which he clearly defined the science of data as a discipline that studies the life cycle digital data - from appearing before converting to represent other areas of knowledge. However, only in the 1990s term for a discipline widely use, and only in the early 2000s has become recognized primarily due to article statistics Bell Labs William Cleveland, where he published a development plan for the technical aspects of statistical research and highlighted the science of data as a separate academic discipline which these technical aspects should be concentrated. 1970s, 1980s, 1990s marked a strong development of database technology. This significantly affects the development of technology information systems. At present use complex in their organizational structure and means of implementation of information systems. The main objective of such systems - to maximize the automation of information processing. The main users of information systems - specialist in this or that area. It was created for him and introduced information systems. On the other hand, information systems improves efficiency and profitability, thanks to automate important processes of information processing. Dozens of years of use in various fields of information systems led to side effects - mountains of data. And under the law of transition quantitative to qualitative changes in dialectical materialism, it is hoped that these mountains filling the knowledge that data passed into knowledge. That is why, since 1990 until now, new technologies associated somehow with data analysis. Consumer technologies such as data mining systems are top management. Such systems in any industry allow reasonable based on historical data, make decisions on development, individual corporations and industries, businesses, government agencies and others.

Since the early 2010s, largely due to the popularization of the concept of "big data", the science of data considered as practical interdisciplinary field of activity, though the specialty "scientists According to" from early 2010s is considered one of the most attractive, well-paid and promising professions. Experts of Master with specialization "The science of data" are able to perform a wide range of duties and hold office Data Scientist, Business Analyst, Technical Lead. At present in Ukraine is only beginning to develop data mining industry. But given the fact that for decades the use of information technology companies and various institutions accumulated a wealth of information, managers are more and more aware that this information contains knowledge that can be used for successful management.

Consider three basic concepts related to data mining.

• OLAP - analyze data in real time; associated with the concept of data warehousing, are all concentrated in a flow of information that accompanies the process in a particular sector in a particular industry, in one way or another corporation; worked well for understanding the retrospective data and test hypotheses;

• Data Mining - extraction of knowledge (ie the knowledge extraction from information accumulated over the years); based on retrospective data to answer questions about the future; the main task - finding new, non-trivial knowledge;

• Big data - a set of approaches, tools and methods for handling structured and unstructured data volumes and huge variety of significant, effective in conditions of continuous growth, distribution to multiple sites of the computer network.

At the beginning of the emergence of these concepts and related technologies each developed as a distinct discipline. Since 2010, they were considered as components of science data [3]. But not only these three concepts are integral. In total the science of information defined as a set of disciplines (Research Areas):

1) fundamental mathematical disciplines;
2) mathematical statistics;
3) programming;
4) artificial intelligence;
5) OLAP;
6) Data Mining;
7) Big data.

Conclusions. The data science is the result of information technology. Information systems as a fundamental information technologies enable accumulation of data over a long period of time. Being able to analyze the data (OLAP-technology) to process large amounts of data (big data) to produce new knowledge (Artificial Intelligence, Data Mining), humanity gets intelligent data processing system on which control anything be more efficient and profitable. This is a challenge for higher education, which must respond to his training specialists in the science of data.

References

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CONTENTS

CONFERENCE HISTORY

Automatics	**1994**	**Kiev**: Glushkov Institute of Cybernetics (GIC) of National Academy of Sciences of Ukraine (NASU)
Automatics	**1995**	**Lviv**: Lviv Polytechnic National University
Automatics	**1996**	**Sevastopol**: Sevastopol National Technical University
Automatics	**1997**	**Cherkasy**: Cherkasy State Technological University
Automatics	**1998**	**Kiev**: National Technical University of Ukraine "Kiev Polytechnic Institute"
Automatics	**1999**	**Kharkiv**: National Technical University “Kharkiv Polytechnic Institute”
Automatics	**2000**	**Lviv**: State Research Institute of Information Infrastructure
Automatics	**2001**	**Odessa**: Odessa National Polytechnic University
Automatics	**2002**	**Donetsk**: Donetsk National Technical University
Automatics	**2003**	**Sevastopol**: Sevastopol National Technical University
Automatics	**2004**	**Kiev**: National University of Food Technologies
Automatics	**2005**	**Kharkiv**: National Technical University “Kharkiv Polytechnic Institute”
Automatics	**2006**	**Vinnytsia**: Vinnytsia national technical university
Automatics	**2007**	**Sevastopol**: Sevastopol National University of Nuclear Energy and Industry
Automatics	**2008**	**Odessa**: National University "Odessa Maritime Academy"
Automatics	**2009**	**Chernivtsi**: Yuriy Fedkovych Chernivtsi National University
Automatics	**2010**	**Kharkiv**: Kharkiv National University of Radio Electronics
Automatics	**2011**	**Lviv**: Lviv Polytechnic National University
Automatics	**2012**	**Kiev**: National University of Food Technologies
Automatics	**2013**	**Mykolaiv**: Admiral Makarov National University of Shipbuilding
Automatics	**2014**	**Kiev**: National Technical University of Ukraine "Kiev Polytechnic Institute"
Automatics	**2015**	**Odessa**: Odessa National Polytechnic University
Automatics	**2016**	**Sumy**: Sumy State University
Automatics	**2017**	**Kiev**: National University of Life and Environmental Sciences of Ukraine

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