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EVALUATION OF THE FUNCTIONAL STATE OF THE CARDIOVASCULAR SYSTEM USING MAGNITUDE VARIATION OF THE PHASE TRAJECTORIES OF SINGLE-CHANNEL ECG

Introduction: The new approach to the assessment of the functional state of the cardiovascular system during screening examinations based on the analysis of the phase portrait's features of a single-channel ECG is developed. Our previous studies have shown that using of new diagnostic features of the phase portrait single channel ECG is possible to increase the sensitivity and specificity of diagnosis even in cases where traditional analysis of 12-lead ECG is uninformative. We assume that the degree of dispersion of the phase portrait trajectories of single-channel ECG may incur an additional diagnostic value as a predictor of the adequacy of the "degree of randomness" of the functioning of the system with regard to its level of development, gender and individual characteristics of the organism.

The purpose of the article is experimental verification of this hypothesis on clinical material.

Methods: Studies were conducted using a hardware-software complex FASEGRAPH that implements information technology processing of the first standard lead of ECG on the phase plane. In contrast to well-known works, in which a single-channel ECG phase portrait is studied on a plane $z(t), z(t - \tau)$, where $\tau = \text{const}$ is a time delay, the complex constructs the phase portrait in the coordinates $z(t), \dot{z}(t)$ where $\dot{z}(t)$ is the rate of change of the signal of the electrical activity of the heart. Due to this we take into account not only the amplitude but the speed characteristics of the test process. We investigate the diagnostic value of indicator σ which characterizes the dispersion of ECG's trajectories obtained from 129 female and 192 man from 6 to 76 years old. Our goal was to study the dependence of the indicator of age and gender. A secondary objective was to compare values of indicator σ with the level of fitness.

Results: It was established that with increasing age the indicator σ tends to increase among women and to decrease among men. Indicator's changes relative to the average values was as high as 15% ($p < 0,05$). Children under 12 regardless of gender demonstrate a wide range of changes of the indicator which was an average 22.5% ($p < 0,05$) higher than the rate of an adult. By increasing the external load among male athletes the increase in the index σ exceeds the increase in heart rate. The opposite trend is observed among woman-athletes. By increasing the external load in persons who are not involved in sports, regardless of their sex an increasing of the heart rate exceeds the increase in the indicator σ . Among athletes the indicator σ changes in waves under increasing the load while in the non-sporting group the indicator σ increases monotonically. Quantitative changes of the indicator σ under urgent and long-term adaptation is directly related to the optimal switching high-frequency components of heart rate regulation.

Conclusions: The dispersion of single-channel ECG's trajectories in the phase space obtained by measuring of the indicator σ can be used as an additional criterion for evaluating the effectiveness of the management the cardiovascular system's functional state.

Key words: information technology, the phase portrait of ECG, criterion.

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INFORMATION TECHNOLOGY FOR MOVEMENT CONTROL OF THE HAND USED TO RESTORE THE MOTOR COMPONENT OF SPEECH

Introduction: Cerebral strokes not only lead to disorders of the motor functions, but also, in 50–60% of cases, of the speech. In our previous studies we developed structural and functional model of the speech motor component restoration based on connecting an external circuit of the purposeful control of forced muscle movements of the hand to the patient. The central part of this circuit is a programmed electrical muscle stimulator. Further studies are aimed at solving practical problems of technology synthesis of speech restoration.

The purpose of this research is to develop an information technology of purposeful control of hand movements to restore the motor component of speech as well as to conduct clinical trials of the technology.

Method: The technology under consideration is based on programmed electrical muscle stimulation method.

Results: Mechanisms of neural plasticity, link between speech development and the development of finger movements as well as proximity of centers of speech and hand representation in the cerebral cortex, all serve as the theoretical grounding for the synthesis of information technology of movement control of the hand to restore speech.

Training programs serving as data signals to control the movements of the hand, methods of transmission of these signals, types of fine motor hand movements, and topology of transmitting the signals to the muscles to control these movements, were all considered as components of this technology. The structural and functional model for speech recovery based on the information technology of purposeful control of fine motor hand movements was presented.

Training of fine hand movements based on the electrical stimulation driven by artificially synthesized programs leads to the formation of new motor centers for the hand and speech. The “Donor” program (the mirroring program), in which the nonparalyzed hand is fit with a sensor to record voluntary fine motor hand movements, and the opposite affected hand is fit with surface electrodes to active the paralyzed muscles, enables to mobilize additional mechanisms of neural plasticity. The criteria for selecting fine hand movements used in speech restoration encompassed development of fine motor skills of the hand in ontogeny and availability of motor points of muscles during electrical stimulation with surface electrodes.

The results of clinical trials of the technology in the complex of rehabilitation measures used to restore speech in post-stroke patients with motor aphasia and its analysis show improvement in language function in 63% of patients, compared to improvement rates of 40%, when the traditional course of rehabilitation is followed.

Conclusions: Use of information technology in purposeful control of fine hand movements in the rehabilitation of stroke patients contributes to the restoration not only of hand movements but also of speech.

Keywords: information technology, purposeful control, programmed stimulation, fine hand movements, structural and functional model, speech restoration, neural plasticity, clinical trials.

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ON OPTIMAL SEARCH ORDER IN THE GROUP SECRETARY PROBLEM

Introduction: We consider a problem of choosing the best item for the case when the elements are divided into groups and performed in a single step simultaneous viewing of elements of the group.

A case, when the objects are divided into groups and carried out simultaneous viewing of candidates in each group, is considered in [3]. After watching the group of candidates the decision procedure is similar to the classical problem, namely: if the group presents the best candidate among all previously viewed items (such an element is called a maximum) to make a decision to choose this candidate and finish viewing or reject it and continue, the returning to the previously rejected candidates is prohibited.

In this case the optimal rule for selecting the best candidate based on the so called “choice theorem” (or “Bruce’s theorem”) is considered in [4] because maximum elements arising may be interpreted as independent Bernoulli trials with different probabilities of success. In this connection a natural question arises: in what order one should view groups that maximize the probability of selecting the best candidate.

Purpose: We try to find the best order of viewing groups which maximize the probability of selecting the best candidate, provided that optimal stopping rule, based on the “Bruce’s theorem” is applied and we compare this probability for the best and the worst cases. As may be expected, the lower bound for the worst case is the probability to find the best element at the classical secretary problem, i.e. $1/e$.

Results: At first we prove two lemmas concerning the form of the optimal order of viewing groups, allowing to understand the structure of optimal solutions. The knowledge of structure helps to shrink the search to some class of permutations (considerably more narrow, then the initial set) of groups. Then we constructed genetic algorithm which finds the approximate optimal solution.

Conclusion: The sequence of groups that maximize the probability of successful choice at the generalized secretary problem must follow the certain rules, that are formulated as lemma 1 and 2. Nevertheless, permutation number that are follow the mentioned rules remains big enough and it impossible to consider all of them directly.

The genetic algorithm finds the approximate solution numerically with high precision. For the case of three groups the exact rule and correspondent probability of success are obtained.

Keywords: optimal choice, secretary problem, Bernoulli trials, group search, genetic algorithm.

A.V. Gummel

STUDY OF A CONTROL PROCESS SYNTHESISED USING APPROXIMATE MODEL WHICH IS IDENTIFIED UNDER BOUNDED ERROR CONDITIONS

Introduction: Majority of existing control methods consider that mathematical model of controlled object is given a priori. If the model is unknown, then identification methods are applied. This methods allows to retrieve a model of researched object using an input and output data which obtained from conducted on object experiments. In case when experiment information contain stochastic white noise bias model structure and parameters can be recovered in a way that accuracy of identification is sufficient to apply existing methods of robust synthesis and obtain acceptable control to get required properties of closed loop system. If only known information is only some boundary of an errors full recovery in many cases is impossible. This study deals with the problem of control synthesis using model obtained by system identification from information affected by bounded error. Such models with given identification conditions can only represent a reduced dimension approximation of original system. Previous research managed to develop identification methods allowing to get approximation models, precision of which is consistent with bias in original data. For linear stationary systems such methods consist of two essential stages. On first stage model structure is determined using singular values as result of SVD procedure applied to input and output information matrices. Second stage is to determine parameters of model given structure of model.

The purpose of this paper is to determine to what extent identified approximating models are suitable for solution of practical problems, how this models should be used in control synthesis problems and ultimately offer a reasonable method of solving control synthesis problem using identified model.

Results: Paper describes identification process and following control synthesis to assure target properties of system with feedback. The modified 4SID-method is used for indentification. Feedback control is synthesized using poles positioning principle and asymptotic state identification of system. Data is obtained using numerical modeling allow to make some evaluation of synthesized control quality.

Conclusions: Based on the results obtained during the research it is possible to state that identified approximating models can be used to change the dynamic characteristics of original unknown system.

Properties of synthesized control can allow to get a system with feedback that has shorter settling time and keep required level of output signal. Whereas bias in system with feedback will stay within error boundaries of initial system or at least overshoot will be insignificant. However further decrease of settling time will lead to increase of bias level of system with feedback, thus such synthesis should be considered as a trade-off between acceptable bias level and required speed of transient response.

Keywords: system identification, control synthesis, 4SID, asymptotic state identification.

V.V. Pavlov, Y.M. Shepetukha

ISSUES OF NET-CENTRIC SYSTEMS ANALYSIS AND SYNTHESIS

Introduction: New scientific endeavors connected with the creation of net-centric concept as well as the development of net-centric systems are widely used in different fields of human activity. Advanced computer and communication technologies allow a real-time modeling of distributed functional and operational components for complex applied processes.

The purpose is the elaboration of methodological issues related to analysis as well as synthesis of net-centric systems with high dimensions and complex configurations.

Methods: General system theory, conflict resolution theory, invariant systems synthesis, theory of deterministic chaos, methods of chaos synchronization and control.

Results: In addition to the traditional taxonomy, specifying man-machine systems operating under the conditions of certainty, risk or uncertainty, it is proposed to distinguish systems working within the so-called “deterministic chaos” when small variations of initial conditions generate completely different phase trajectories. Methodology for the development of net-centric structures should be based upon a system integration of interacting functional and operational components. Modeling of applied processes allows to examine possible scenarios that describe originating of system’s chaotic behavior. The proposed approach could also be used for both quantitative and qualitative analyses of essential parameters’ influence on different options for a recovery of net-centric systems’ organized state.

Conclusions: An important issue of research in the field of net-centric systems is recognition and structuring of specific functional and operational elements coping with internal as well as external information flows. Examination of applied processes in distributed network structures gives a possibility to distinguish various models of chaotic behavior: discrete models, finite phase space ones described by ordinary differential equations (systems of Lorenz, Rossler, etc.), infinite phase space models governed by ordinary differential equations with delays (system of Ikeda, etc.). Another significant problem of net-centric systems’ construction is the examination of a way from chaotic to organized state of the system. Such a backward transition could be performed with the use of modification for essential variables of information exchange process.

Keywords: applied process, net-centric system, chaotic behavior, chaos control, non-linearity, unstable phase trajectory, synchronization, feedback.

A.A. Trizna, S.A. Yankova

AREAS OF PRACTICAL APPLICATION OF INDICES OF AIRCRAFTS MAINTENANCE AND THEIR GROUND BY METHOD OF THE GENERALIZED ENTROPIES

Introduction: There is a necessity of classification and specification of determinations of aircraft maintenance indexes and criteria.

In theory, the technical operation is now entering its second phase. Its generalized characteristic is to consider not operating as an independent phase, and as the central stage in the life cycle of the existence of industrial products, the need for advanced classification and clarify the definitions and criteria of technical manuals; generalized analytics system properties (efficiency, reliability, maintainability, durability, cost and etc.) and use these combinations of properties.

The purpose of the article is aircraft maintenance and engineering psychology indexes as complex policomponent probabilistic values of these indexes and determination of area of their practical applicability.

Results: Regularity researches of additive and multiplicative measures show that at the increase of number of components in an index the area of practical applicability of additive index passes to the area of small probabilities and multiplicative — to the area of high probabilities.

The developed table with nomograms for the engineering calculation of practical application of complex policomponent probabilistic values domains allows to define a practical application of these indexes domain at the estimation of aircraft maintenance.

Conclusions: Theory and practice of technical operation of the aircraft is currently at the stage of organizing and summarizing data. In order to organize, you need to generalize the use of such approaches as a process approach, process analysis and generalized theory of processes. Analysis of indicators of aircraft operations showed that the calculation of areas of their practical applicability should be carried out by the generalized entropy process. Developed classification performance of aircraft operation, which is based on the consideration of these indicators as multicomponent probability values (measures) to determine the area of practical application of these indicators when assessing the technical operation of aircraft.

Investigation of the laws of the additive and multiplicative measures showed that increasing the number of components in the index, the area of practical applicability of the additive indicator moves to the low-probability, and multiplicative function in the region of high probability.

Keywords: Aircrafts maintenance, engineering analysis, indices of maintenance, entropy, nomogram.

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METHODS TO ESTIMATE PATIENT'S GRADE OF SEVERITY

Introduction: One of the actual tasks in developing medical decision support systems is forming of decision rules, which serve for patient's grade of severity estimation. Since medical data are mostly random variables, the most appropriate techniques for mathematical modeling in medical applications are stochastic, probabilistic and statistical methods of multivariate analysis.

The purpose of the paper is to develop the methods for patient's grade of severity estimation, which involve the method to construct classifiers, and methods to form their compositions.

The method for classifiers constructing is based on the metric approach to graphical representations (maps or plots) generated by statistical methods of geometrical representation of data structure (multidimensional scaling and correspondence analysis). The key point of the method developing is that we represent "classes" not as some subspaces or areas of compact layout in objects' space, but as an additional feature of object's description. Using such interpretation of "class" notion we construct the mathematical model of target feature "class" dependence on other explanatory variables.

To construct compositions of classifiers we develop and formalize the method, which we call "rate voting". The method uses weights of basic classifiers, evaluated as functions of basic algorithms' answers for an object, their accuracies in predicting separate classes, and mistakes in prediction other classes. Another method of classifiers compositions constructing were called "seniority rate voting". The method evolves ideas of "rate voting" by combining them with principles of committees with seniority logic. This combined method turns to be more relevant and effective in some practical applications.

Results and Discussion: The applying results of the methods suggested are reported in the paper. The mathematical models for patient's grade of severity estimation in a case of pancreas trauma and traumatic pancreatitis, for differential diagnostics of bile-excreting ducts diseases, for clinical outcome prediction in a case of cerebral strokes and pancreas traumatic injuries, were developed. It is shown that overall accuracy, sensitivity and specificity of these models are greater than of those, which were developed on the basis of the common mathematical-statistical modeling methods.

Conclusions: The methods to construct classifiers and their compositions, which are reported in the paper, allow improving of overall accuracy, specificity and sensibility of patient's grade of severity estimation.

Keywords: patient's grade of severity estimation, supervised classification method, compositions (committees, ensembles) of classifiers.