CONTENTS AND ABSTRACTS

RADIO ENGINEERING AND RADAR

V. G. Andreyev, V. A. Tran. OPTIMIZATION OF STATISTICAL MODELS FOR PIECEWISE-STATIONARY RADIOENGINEERING SIGNALS

Key words: piecewise-stationary noise, weight vector, adaptive algorithm, autoregressive model, moment disorder, spectral estimation, power spectral density.

The optimization of mathematical description for piecewise-stationary radioengineering signals has been carried out. The structure of the algorithm and the proposed method of statistical description are presented. The aim of the work is to increase the computational efficiency of analysis algorithms, and the accuracy of spectral estimation for radioengineering signals on the background of piecewise-stationary noises. The qualitative indicators of the proposed modified spectral analysis method are compared with the conventional autoregression method. Experimental studies have shown that by using the approach proposed for spectral estimation, when compared with known autoregressive methods, it is possible to reduce the discrepancy between control and estimated spectra by 5.2...7.5 times. When conducting a comparative analysis and determining efficiency with a conventional autoregressive model, a decrease in the order of p can be up to 3...5 times. The authors have been confirmed that analyzing the spectrum of radioengineering signals under study relative deviations ΔF of dominant frequency estimate are significantly (up to 6 times) reduced by using the proposed modified method in comparison with autoregressive method. Winnings are achieved through the use of a priori information about time-varying power of interfering process.

V. K. Klochko, **V. P. Kuznetsov**, **Vu Ba Hung**. ESTIMATION OF RADIO SIGNAL PARAMETERS FROM MOBILE LOW-ALTITUDE OBJECTS

Key words: Radio signals, parameter estimates, mobile low-altitude objects, mathematical and computer modeling.

The problem of estimating quasi-continuous radio signal parameters from low-altitude and low-size moving objects is considered. Methods and conditions for improving the accuracy of spatial coordinate estimates of objects are investigated. The aim of the work is to increase the efficiency of radio systems for observing low-altitude and low-size moving objects. The study is carried out by mathematical and computer modeling of radio signal models and estimating their parameters. It has been shown that the accuracy of estimates can be improved by taking into account the sphericity of wave front. Comparative evaluation of radio system operation efficiency in signal processing in frequency and time areas is given. The simulation results are given. The applied focus of the work is the algorithmic support of radio systems for protecting small territories from low-altitude moving objects.

D. I. Popov. PROCESSING OF NON-EQUIDISTANT SIGNALS AGAINST PASSIVE INTER-FERENCE BACKGROUND

Key words: processing algorithms, algorithm analysis, repetition period wobble, Doppler phase, correlation matrix, passive interference, probability density, radial velocity, block diagram of signal processing system.

The processing of non-equidistant coherent pulse radar signals in the presence of passive interference is considered. The aim of the work is synthesis and analysis of algorithms and systems for processing non-equidistant coherent pulse signals. A statistical description of radar signals and interference during the period of repetition of probing pulses is given. Based on the likelihood ratio, the algorithms and the corresponding system for optimal processing of non-equidistant signals of moving targets against passive interference background are synthesized. A block diagram of optical processing system is presented including matrix filter, weighing unit and multi-channel filter. The measurement of target radial velocity by a channel number in which the signal was detected is considered. The condition for choosing the parameters of wobble law is given, which provides unambiguous measurement of radial velocity over the entire range of real target speeds. The analysis of synthesized processing algorithms is carried out depending on correlation properties of interference and wobble parameters. The results of the analysis set the limit to which the efficiency of real signal processing systems should strive.

S. N. Razinkov, **A. V. Bogoslovsky**, **D. N. Borisov**, **E. V. Syomka**. EVALUATION OF EFFECTIVE SCATTERING AREA FOR UNMANNED AERIAL VEHICLE

Key words: unmanned aerial vehicle, effective scattering area, radio channel energy equation, electrodynamics modeling.

Based on spectral energy equations for transmission and reception of inharmonic wave processes in a radio channel with scattering, estimates for the detection range of medium-altitude unmanned aerial vehicle of "Eitan" aircraft type by radar stations with broadband signals are obtained. The sections of frequency ranges with the highest level of secondary radiation of radar objects are determined and the possibilities of increasing the energy of radar information signals due to the rational choice of antennas with partial directional coefficients that allow achieving maximum efficient moments of radio channels are investigated.

Using three-dimensional solid-state and surface parametric design system of Solid Works, a volumetric digital model of unmanned aerial vehicle "Eitan" was created and, based on the results of numerical solution of boundary-value problems in the Altair FEKO electrodynamics modeling computer program, an analysis of its effective scattering area in the C-band was carried out.

Based on the results of flight experiments, radar images were obtained, on the analysis of which the background contrast of hull elements was determined and dominant centers of secondary electromagnetic radiation of Eitan unmanned aerial vehicle were identified.

The aim of the work is to analyze the reflective properties of unmanned aerial vehicle "Eitan" in the sectors of angles and frequencies and its background contrast during radar surveillance.

It is shown that with linear polarization of irradiating and reflected signals in the frequency range of 5.2...5.5 GHz, maximum effective scattering areas of unmanned aerial vehicle "Eitan" reach 0.05 ...0.14 m^2.

Nguyen Trong Nhan, A. S. Podstrigaev. EXPERIMENT VERIFICATION RESULTS OF SIGNAL TYPE RECOGNITION ALGORITHM IN AUTOCORRELATION RECEIVER

Key words: simple signals, chirp signals, PSK signals, signal type recognition, detection characteristics, autocorrelation receiver, mathematical model, RF spectrum monitoring.

We consider the task of studying the efficiency of autocorrelation receiver (ACR) for RF spectrum monitoring on real signals. The work aims to conduct experimental testing of the mathematical model of signal type recognition algorithm (simple, chirp and phase-shift keyed (PSK) signals) in ACR. Comparison of detection characteristics for imitated and real signals in the ACR of RF spectrum monitoring means is carried out. Experimental verification of the mathematical model for signal type recognition algorithm in the ACR showed the following: a mathematical model makes it possible to effectively identify the type of signal when SNR is more than –2 dB; under identical processing conditions, a chirp signal has the highest probability of correct recognition; identification of real simple, chirp and PSK signals requires SNR of 0.2...2 dB more than the identification of similar simulated signals. The research results can be used to develop RF spectrum monitoring means.

MATHEMATICAL AND COMPUTER SYSTEMS SOFTWARE AND COMPUTER NETWORKS

D. A. Perepelkin, K. V. Anisimov. DEVELOPMENT OF ARCHITECTURE AND SYSTEM OF FUZZY METRICS FOR COMMUNICATION LINKS OF SOFTWARE DEFINED NETWORK OF INTERNET OF THINGS DEVICES

Key words: Internet of Things, software defined network, OpenFlow, fuzzy logic, fuzzy inference.

In the past few years, manufacturers of various electronic equipment have begun to massively implement Internet connectivity in their products. This applies not only to industrial devices that need access to data from external sensors, but also to household appliances and electronics for small and medium-sized businesses. The ability to control devices or receive data from them remotely has proven to be very convenient for a consumer. Simultaneously, current development of software defined networks (SDN) technology has made it possible to more flexibly manage data flows compared to classical computer networks. The aim of the work is to develop the architecture and the system of fuzzy metrics for communication links of a software-defined network of Internet of things devices. The paper proposes a five-level architecture of a software-defined network of Internet of Things devices and develops its mathematical model. To configure the network, metrics that are obtained using fuzzy inference are proposed.

K. I. Nikishin. MODELING AND VERIFICATION OF SOFTWARE DEFINED NETWORK TOPOLOGY

Key words: Software Defined Networks, topology, controller, switch, Ethernet, OpenFlow, Petri Nets, CPN Tools.

The complexity of managing Ethernet switches, routing tables and other network parameters allowed us to offer the technology of Software Defined Networks (SDN). With the help of SDN networks, the approach to managing and administering many network parameters in network infrastructure is simplified. The article discusses the architecture and layers in SDN networks. Topologies in SDN networks are considered: with single,

distributed and hierarchical SDN controllers. The aim of the study is to research various topologies in SDN networks using colored temporal hierarchical Petri nets. The objectives of the research are to research behavioral and temporal functioning of SDN network models as well as their verification for dead-end states, transitions and analysis of state spaces. The developed models made it possible to verify the SDN network algorithms in various configurations.

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K. I. Nikishin. CONTROLLER MODELING AND DATA TRANSMISSION VERIFICATION IN SOFTWARE DEFINED NETWORKS

<u>Key words:</u> Software Defined Networks, controller, switch, Ethernet, OpenFlow, invariants, Flow Table, Petri Nets, CPN Tools.

The complexity of managing Ethernet switches, routing tables and other network parameters allowed us to offer the technology of Software Defined Networks (SDN). The switches and the SDN controller communicate via the OpenFlow protocol, which is responsible for receiving and transmitting traffic and updating flow tables. The article discusses modeling and verification of the SDN controller, OpenFlow, Flow tables. The aim of the research is to study and build a frame transmission model in SDN networks, study and build models of a controller and entire SDN network system with multiple switches and end nodes hosts and work with the Flow Table using Petri nets. The objectives of the research are to study behavioral and temporal functioning of various models of SDN networks, as well as their verification using invariants. The developed models made it possible to verify SDN network algorithms during traffic transmission, controller and switch operation in the SDN network and the OpenFlow protocol.

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M. S. Pestin, A. S. Novikov. MULTIPATH TRAFFIC ROUTING ALGORITHM IN MANET NETWORKS BASED ON COMMUNICATION CHANNEL BANDWIDTH ANALYSIS

<u>Key words:</u> MANET, mobile decentralized self-organizing networks, traffic routing, reactive routing, routing metric, network protocol, wireless network simulation model, data delivery reliability.

The article discusses an approach to traffic routing in mobile decentralized self-organizing communication networks (MANET). The aim is to increase the reliability of data delivery in MANET networks by using the algorithms proposed by the authors for detecting routes in wireless data networks and routing traffic in them, taking into account the balancing of network flows depending on the bandwidth of individual channels. The proposed approach is based on the principles of reactive routing protocols for wireless decentralized communication networks. As route metrics, performance indicators of channels and subscribers that are part of the route are selected. They are used to calculate two fitness functions. One of them is used to assess the suitability of partially or fully formed routes for further use, as well as for their mutual comparative analysis. The second is used to calculate the proportions in which traffic will be distributed over different routes, thus balancing the data flows in the network. For the experimental study of the proposed algorithms, a simulation model of a wireless decentralized network was developed. An experimental study has demonstrated an increase in the reliability of data delivery between two given subscribers compared to standard algorithms of the AODV protocol.

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A. N. Saprykin, **N. Yu. Yurkov.** DEVELOPMENT OF AUTOMATED SYSTEM FOR COMMUNICATION WITH USERS IN DISTANCE LEARNING SYSTEM

Key words: automated communication system, human-machine interaction, distance learning system, chatbot, Moodle, Telegram.

The problem of implementing the interaction between an automated system for communication with users and distance learning system as well as providing additional access to the system through instant messaging program is considered. The aim of the work is to develop software for automatic communication with users in distance learning system. Software architecture and tools for human-machine interaction are proposed. A general functional diagram of the interaction between the developed automated system and distance learning system with a detailed analysis of the functioning of each block is presented. A class diagram of the developed system has been compiled. The function of requesting the information being interesting to the user on current training courses, assessments and educational materials through a messenger connected to distance learning system has been implemented.

INTELLIGENT INFORMATION SYSTEMS
AND TECHNOLOGIES

K. V. Bukhensky, A. N. Konyukhov. ANALYTICAL IMPLEMENTATION OF CENTROID DEFUZZIFICATION METHOD AFTER AGGREGATION OF MAMDANI IMPLICATION CONSEQUENTS

Key words: fuzzy set, LR-type fuzzy number, membership function, shape function, antecedent, consequent, Mamdani inference, linguistic variable term, defuzzification, center of gravity (COG) method.

The aim is to obtain analytical COG defuzzification formulas for aggregated consequents of Mamdani inference using LR-representation of linguistic variable (LV) terms. There are two requirements: 1) possibility to express analytically inverse functions to shape functions of LR-type fuzzy number (FN); 2) possibility to integrate analytically a shape function $F(t)$ and $(1-t)F(t)$ being a shape function as well. The technique was demonstrated for arbitrary number of output LV terms described by FNs with different shape functions of five types. Three thousand uniformly distributed random vectors of rule firing strengths were generated to verify formulas. Defuzzification time is shown to be reduced by more than two orders of magnitude. The results obtained could be used for fuzzy controller performance and fuzzy design software enhancement. Analytical representation makes further optimization of COG defuzzification method and its modifications possible.

I. Yu. Kashirin. APPLICATION OF HIERARCHICAL NUMBERS THEORY IN ICF TAXONOMY DESIGN FOR NEURAL NETWORK OPTIMIZATION

Key words: Data Mining, learning algorithms, transformation rules, ICF taxonomy, hierarchical numbers, semantic proximity, clustering, neural networks.

The article considers a new approach to the design of neural networks using ICF-ontologies, structured in accordance with certain transformation rules. The rules are described using the theory of hierarchical numbers. Applied ICF ontology is used to describe the semantic part of input data of training sample based on the calculation of semantic similarity of concepts and features.

The model of knowledge, redesigned on the basis of transformational rules, allows us to optimize input data sets for big data mining. Software implementation of the proposed approach is based on learning data analysis algorithms. The experiments performed using Python v.3 (Anaconda 3) toolkit show the effectiveness of formal data conversion apparatus described in the article.

The aim of the work is to create a science-intensive technology for designing Data Mining algorithms with training to solve big data analysis problems based on the application of hierarchical numbers theory.

O. D. Kazakov, N. Yu. Azarenko. AUGMENTATION OF AUDIO DATA FROM CYBER-PHYSICAL LEVEL OF DIGITAL TWINS OF TECHNOLOGICAL SYSTEMS

<u>Key words:</u> digital twin, technological system, audio data augmentation, cyber-physical level, transfer learning.

The problem of audio data augmentation from cyber-physical level of digital twins of technological systems is considered. The aim of the work is to evaluate quality metrics of equipment health classification models trained on the same neural network architectures with the same configured hyperparameters, but on different datasets: original and extended based on the proposed approaches: 1) random blocking algorithm for sequential frequency range, i.e. blockages of certain sections of the spectrogram; 2) adding Gaussian noise to the spectrogram. Augmentation of the data obtained during the operation of pumping station AL-KO HW 3600 Easy 113798 at the stage of designing the cyber-physical level of its digital copy made it possible to increase the data set to 392 objects. The values of F-measure of Transfer learning test set on the extended data set after augmentation based on the proposed algorithms are in all cases higher than on the original data set. This study makes a certain contribution to the increased application of deep learning neural networks for diagnosing equipment failures. The proposed methods will make it possible to achieve high diagnostic accuracy with a small initial data set, and also solve the problem of improving safety and reliability of technological system operation in real conditions.

MATHEMATICAL AND COMPUTER MODELING

K. A. Maikov, A. N. Pylkin, S. N. Kuzmenko, A. A. Teplov, A. A. Bubnov. MODELING AND ANALYSIS OF GROWTH PATTERNS OF THREE-DIMENSIONAL REGULAR AND STOCHASTIC FRACTALS

<u>Key words:</u> three-dimensional fractals, three-dimensional fractals growth, geometric fractals, stochastic fractals, fractal construction algorithms, fractals metric characteristics.

The growth of fractal complex is modeled by classical, single-phase, multiphase and stochastic algorithms. The method of analysis of growth processes is proposed, their main characteristics are considered. Fractal regularities of growth metric characteristics, their transformation when changing a growth algorithm are revealed. The effect of stochastic changes of fractal elements on the process of its growth is modeled. A number of fractal growth general patterns of structures are formulated. It is shown that algorithms and methods used to analyze growth processes have great potential for modernization and adaptation to a wide range of tasks. A generalized algorithm for the growth of three-dimensional regular and stochastic fractal structures is proposed, the distinctive

feature of which is the variability of algorithm choice from the problem being solved. Software implementation of the proposed algorithm confirmed the validity of the solutions considered in the study and modeling of three-dimensional fractals growth.

S. I. Frolov, **E. A. Danilova**, **V. A. Trusov**, **I. I. Kochegarov**, **N. K. Yurkov**. TO THE QUESTION OF SIMULATING NATURAL FREQUENCIES OF OSCILLATIONS IN MULTIFACETED PRISMS OF RESONANTLESS STRUCTURES OF ONBOARD RADIO-ELECTRONIC EQUIPMENT

Key words: cylindrical shell, polyhedral prism, natural oscillation frequency, mathematical modeling, vibration, resonance, protection against mechanical impacts, thin-walled structures.

The article presents the results of work on the development of an engineering method for calculating resonance-free prismatic thin-walled structures. Studies of natural frequencies of vibrations in multifaceted prismatic structures of on-board radio-electronic equipment are carried out. Simulation of natural oscillation frequencies for different number of faces and varying wall thickness of polyhedral prisms is carried out. Numerical solutions of test problems using a mathematical modeling package are presented, conclusions are drawn and recommendations are given for the creation of non-resonant, in a given vibration frequency range, thin-walled prismatic structures at the early stages of designing on-board electronic equipment. Graphs of the dependence of natural oscillation frequency on the number of faces of polyhedral prisms for different wall thicknesses are obtained, and the discrepancy between analytical and numerical solutions is estimated. It is shown that an increase in the number of faces leads to the degradation of ribs and changes in the properties of a cylinder. The possibility to use analytical dependence of determining natural frequency of vibrations of prismatic block structures for practical use is proposed and justified.

SYSTEM ANALYSIS, MANAGEMENT
AND INFORMATION PROCESSING

A. V. Levitin, V. S. Muraviev. DETECTION OF TEXTURE ANOMALIES IN SKIN IMAGES

Key words: classification, segmentation, texture, descriptor, skin image, support vector machine, Gaussian mixture model, local binary patterns.

The solution of the problem for texture detection on images containing abnormal areas using one-class support vector machine (one-class SVM) and Gaussian distribution mixture model (GMM) is considered. Similar problems may arise in various applications, e.g., in quality control of product manufacturing. Texture descriptors based on local binary patterns (LBP) that are invariant to image rotation are used as image features in this work. The aim is a statistical study of the above approaches, which shows the advantage of support vector machine to solve the problem in the formulation presented. During the research the algorithm parameters have been adjusted to provide the best results. Segmentation results of skin textures with image processing in a "jumping" window using support vector machine are given.

I. S. Kholopov, **T. S. Kislitsyna, E. S. Shtrunova**. LINEAR OPERATOR TO DETECT OBJECT EDGES WITH A PRIORI SPECIFIED ANGULAR ORIENTATION IN A DIGITAL IMAGE

Key words: brightness gradient, edge detector, Prewitt operator, Nevatia – Babu operator.

The aim of the work is to develop a linear two-dimensional operator that implements the calculation of a brightness gradient in a digital image in a priori given angular direction. The geometric statement of the problem and the algorithm for calculating the weight coefficients of linear filter mask are given. It is shown that the developed linear operator makes it possible to successfully detect edges with user-defined angular orientation when signal-to-noise ratio is more than 10. An example of using a linear operator in an applied task of measuring the distance to objects on a railway using information from a single camera frame is given.

N. A. Smolyarov. RELIABILITY OF RESTORABLE SYSTEM WITH LOAD-MIXED RESERVE

Key words: reliability, redundant restorable system, load-mixed reserve, common and individual switches, mean operating time between failures, reliability gain to mean operating time between failures.

Finding problem of mean operating time between failures of restorable system with load-mixed reserve, common and individual switches is considered. The aim of the article is to obtain correlations allowing to estimate mean operating time between failures of this system with redundancy ratio $m = 2$ taking into account switches unreliability. Markovian model of system reliability is used. As a result of problem solution the expressions for calculating mean operating time between failures, estimation of reliability gain to it from considering system application as compared with restorable system with loaded reserve are obtained. These expressions may be used with any type of reserve on a load and with the execution of the assumptions received.

PHYSICAL ELECTRONICS AND NANOELECTRONICS

A. E. Malyutin, **V. V. Ivanov**, **Yu. V. Cherkasova**. ANALYTICAL REPRESENTATION OF ION CAPTURE COEFFICIENT IN QUADRUPOLE ION TRAP

Key words: mass spectrometry, quadrupole ion trap, ion capture coefficient, phase space, capture ellipses.

The aim of the work is to research the possibility of applying an analytical approach to solve the problem of the effectiveness of quadrupole mass spectrometers. The theoretical derivation of expressions describing ion capture coefficient in a quadrupole ion trap, taking into account the distribution of their initial parameters in phase space, is made. Several possible distributions of initial parameters are considered: point ionization region, axial ionization, ionization by a ribbon beam and the input of ions from the outside. It is shown that in all cases it is possible to obtain analytical expressions for ion capture coefficient or sufficiently accurate analytical approximations.

S. A. Kruglov, A. A. Serezhin, D. S. Kusakin, K. D. Agaltsov. ANALYSIS OF TRANSIENT PROCESSES CONSIDERING LOSSES IN GAS-DISCHARGE CURRENT SWITCH WITH SECTORAL SCREEN HOLE

Key words: gas-discharge current interrupters, low-pressure plasma, effect of current self-break, inductive energy storage, critical charge, energy losses of a gas-discharge switch.

The work is devoted to the study of energy losses during the flow of current at the stage of conduction and switching, in a gas-discharge current switch with a shielding electrode having a sector hole, and to evaluate the efficiency of the device in the circuit of a high-voltage pulse generator with inductive energy storage. The aim of the work is to study energy characteristics of operating mode of a gas-discharge current switch with a sectoral screen hole in a circuit with inductive energy storage.

S. A. Kruglov, A. A. Serezhin, D. S. Kusakin, K. D. Agaltsov. INFLUENCE OF GRID NODE DESIGN PARAMETERS IN GAS-DISCHARGE THYRATRON-TYPE CURRENT SWITCH ON DEVICE INTERNAL HEATING

Key words: gas-discharge current interrupters, low-pressure plasma, current self-cutting effect, inductive energy storage, critical charge, grid electrode flange temperature.

This paper presents the results of experimental studies of the effect of changing operating temperature on the operation mode of gas-discharge thyratron-type current switches in a circuit with inductive energy storage. The analysis of the results obtained made it possible to establish that the average settling time of a gas-discharge switch in continuous frequency mode is 20 min. Based on surface temperature distributions of functional units of the device over time, it can be seen that the degree of heating of anode, grid and cathode nodes increases towards anode unit at $U_m \geq 30$ kV, at $U_m \leq 30$ kV the degree of heating increases towards grid and cathode units , due to a change in the ratio of switching losses and conduction losses. In a new gas-discharge switch, it was possible to reduce the heating of grid node by an average of 15-20 %. The aim of the work is to study the effect of temperature on the operation mode of gas-discharge current switches in a circuit with inductive energy storage.