# CONTENTS AND ABSTRACTS

## RADIO ENGINEERING AND RADAR

**V. G. Andrejev, V. A. Tran.** PARAMETRIC SPECTRAL ANALYSIS OF PIECEWISE-STATIONARY RADIOENGINEERING SIGNALS WITH VARIOUS CORRELATION PROPERTIES

Key words: piecewise-stationary noise, non-stationary noise, weight coefficient, adaptive algorithm, autoregressive model, change-point, spectral estimation, power spectral density.

We proposed and investigated a modified method of spectral analysis of piecewise-stationary processes to take into account the influence of additive noise changing power on correlation matrices. The aim of the work is to increase the computational efficiency of analysis algorithms and the accuracy of spectral estimation of radioengineering signals on the background of piecewise-stationary noises. In the process of estimating the optimal value of weight coefficient $\beta$, which determines the shares $\beta$ and $(1-\beta)$ of processes with different statistical properties the method proposed makes it possible to reduce the influence of non-stationary noise and improve the accuracy of spectral estimates by correcting autocorrelation coefficients of piecewise stationary random processes. The qualitative indictors of a proposed modified spectral analysis method are compared with a conventional parametric autoregressive method. Experimental studies have shown that the application of the proposed approach for spectral estimation, when compared to known autoregressive methods, allows reducing the discrepancy between control and estimated spectra by 3.1...5.5 times. When conducting a comparative analysis with a conventional autoregressive model, the decrease in the order of p can reach 2...3 times while maintaining the same spectral estimation accuracy. It is confirmed that for spectrum analysis of narrowband radioengineering signals under consideration, relative deviations $\Delta F$ of dominant frequency estimate are significantly (up to 4 times) reduced by using a proposed modified method in comparison with an autoregressive method. Winnings in the accuracy of spectral estimation are achieved by taking into account changes in autocorrelation properties of the analyzed signal due to the effect of piecewise stationary noise on it, the power of which being changed during observation.

**I. V. Vassilyev, S. M. Saliy, D. B. Syedin.** PECULIARITIES OF CALCULATION OF THE ENERGY POTENTIAL OF METER-WAVE CW RADAR

Key words: UAV, FFT, coherence, chirp, sea target, accumulation, radar, resolution, frequency stability, RCS.

The paper discusses the features of calculating the detection range of marine targets for continuous-radiation radars of meter wave range. The information is provided on the prospects for using meter wavelength range for long-range detection of small targets, such as small boats and unmanned aerial vehicles, which make the development of low-cost mobile radars with chirp signals relevant. Limitations of tactical and technical characteristics of radars associated with the stability of master oscillators, Doppler velocity and the duration of coherent accumulation intervals are shown. The value of radar energy potential loss is estimated when using master oscillators with the frequency stability insufficient for coherent accumulation over long intervals of up to 10 seconds. The example of calculating the energy potential for detecting a boat at a distance of 11

# INTELLIGENT INFORMATION SYSTEMS
# AND TECHNOLOGIES

# MATHEMATICAL AND COMPUTER MODELING

**V. P. Koryachko, D. A. Perepelkin, V. Y. Likuchev.** MATHEMATICAL MODEL OF REPRE-SENTATION OF MULTI-AGENT SYSTEMS AND ITS APPLICATION IN THE PROBLEMS OF TOPOLOGICAL DESIGN OF MODULES OF RADIO-ELECTRONIC DEVICES

Key words: design automation, topological design, placement of elements, multi-agent system, electronic module, printed circuit board.

Topological design of radio-electronic modules consists in solving the problems of placing elements on a printed circuit board and tracing printed conductors. The results of the implementation of these procedures determine the level of reliability and quality of functioning of the modules in the equipment, especially when, due to the working purpose, multiple technical requirements are imposed on it. The most time-consuming at this stage is the procedure for placing elements. During it, the final printed node structure of the module is set and the time of the subsequent connection tracing is determined. The tendency for the complication of electronic equipment means to create new methods, algorithms and tools for automated placement. Their use will reduce the period of topological design, but at the same time maintain or even improve the existing level of product quality. One of the promising areas is the development and research of intelligent design methods, and in particular methods based on multi-agent systems. The aim of the work is to describe one representation model of multi-agent systems for solving the problem of placing elements, to state the key aspects, properties, and also the mathematical formalism of this model.
**DOI:** 110.21667/1995-4565-2023-83-48-61 .......................................................... 48

**K. A. Maikov, A. N. Pylkin, S. N. Kuzmenko, A. A. Teplov.** FRACTAL GROWTH SIMULATION METHOD IN VIRTUAL AND AUGMENTED REALITY TECHNOLOGIES

Key words: three-dimensional fractals, growth of three-dimensional fractals, geometric fractals, stochastic fractals, fractal construction algorithms, metric characteristics of fractals, machine learning, regression.

The development of mathematical apparatus to describe fractals in order to solve the tasks of their growth, to design necessary metric characteristics and relations is offered. The problem of estimating time parameters of growth process by its metric characteristics is solved. An algorithm, the predominant feature of which is the alternate refinement of two-time parameters of fractal structure growth has been developed. The analysis of the results of machine experiments confirmed the practical applicability of a proposed algorithm for solving the inverse problem of fractal growth process.
**DOI:** 10.21667/1995-4565-2023-83-62-71 .......................................................... 62

**V. P. Koryachko, V. A. Minaev, R. O. Stepanov, A. O. Faddeev.** MODELING OF THERMO-ELASTIC DEFORMATIONS AS A SOURCE OF GEODYNAMIC HAZARDS IN THE ARCTIC ZONE

Key words: Arctic, cryolithozone, modeling, geological environment, temperature regime, thermoelastic defor-mations, monitoring.

The article deals with the problem of assessing temperature regime at various depths of Earth's crust, the measurement of which by direct methods is impossible, and known indirect methods are difficult to be implemented. The aim of the work is to construct a mathematical model of lithosphere temperature regime, the solutions of which made it possible to quantify stresses and displacements formed in geological environment due to a complex impact of tectonic and thermal processes on it. The results of quantitative es-

timates of thermoelastic deformations in surface layers of Earth's crust in relation to Arctic cryolithozone of Russian Federation are presented. Based on simulation results, temperature distribution fields are constructed, numerical estimates of displacements and thermoelastic deformations in surface layers of Earth's crust are performed both for the whole of southern Yakutia and for the vicinity of Yakutsk. An important conclusion is made that the presented models make it possible, on a fundamentally new technological basis, to monitor buildings, engineering structures and their ground bases including cryolithozone conditions, to develop sound recommendations on the conditions of safe construction of both individual objects and their complexes, as well as to control a construction procedure on the territories of different size.

# SYSTEM ANALYSIS, MANAGEMENT AND INFORMATION PROCESSING

**P. V. Babayan, E. S. Kozhina.** AUTOMATIC EXTRACTION AND DETECTION OF MOVING OBJECTS USING VIDEOCAMERA WITH VARIABLE FIELD OF VIEW

Key words: object extraction, object detection, background subtraction, scale estimation, evaluation of geometric transformations, multi-template matching, vision system.

The paper considers the problems of extraction and moving objects detection in a sequence of images. To solve the described tasks, a method based on background subtraction is used. The aim of the work is to develop an algorithm that is oriented to work in the presence of scale geometric transformations on an image. To evaluate scale geometric transformations, a multi-template matching approach is used. In the process of developing object detection and extraction algorithm an updated mathematical model of an image has been used. This model takes into account geometric transformations caused by changes in the focal length of a camera or changes in the distance to a scene due to spatial movement of image sensor. The results of experimental studies with various real video sequences are presented. During the research of the algorithm, the influence of scale distortion estimation standard deviation on the quality of object localization has been considered. Based on the results of the experiments, a conclusion about relatively high efficiency of the proposed algorithm has been made. The algorithm developed can be used in computer vision systems of aerial vehicles, mobile robots, in video surveillance systems.

**V. I. Poshekhonov, A. E. Kuznecov, M. M. Egin.** ESTIMATION OF APPROXIMATION ACCURACY FOR STRICT MODEL OF SPACE IMAGING BY RATIONAL POLYNOMIALS

Key words: geocoding, imaging RPC model, strict model for scanner imaging, earth remote sensing, processing levels of earth remote sensing data, «Resurs-P» satellite.

In space systems for earth remote sensing the images of standard processing levels 1 and 2A are followed by rational polynomial coefficients (RPC) that introduce the relation between planar and geodetic pixel coordinates on an image. RPCs approximate strict model of imaging camera and require no deep understanding of its interior and exterior orientation elements. The aim of this paper is to develop the tools for estimation of approximation accuracy for strict imaging model by RPCs and to validate these tools on images of processing levels 1 and 2A acquired from «Resurs-P» satellite series. Based on the conducted experimental research on real data the approximation accuracies for a strict imaging model were estimated for «Geoton» and KShMSA-SR/VR de-

vices. Practical recommendations for end-users regarding the use of RPC coefficients for refined photogrammetric processing were formulated.

**I. V. Rudakov, M. V. Filippov, M. A. Kudryavtsev, D. Yu. Pudov.** EFFICIENCY DETERMINING FOR THE CONTAINERLESS DATA HIDING METHOD AGAINST THE MODERN METHODS OF STEGANALYSIS

Key words: steganography, container, first-order statistics, blind classifiers, neural networks, stegoanalysis, secret message, data hiding.

Article consider the problem of detecting data hidden by the steganographic method developed by the authors. The aim of the article is to review the current methods and tools destined for discovering hidden messages in images, their applicability to assess the reliability of the method developed by the authors. Determine the possibility of detecting the transmission of hidden information and the possibility of extracting hidden data. The article discusses steganalysis methods for algorithms based on first-order statistics, which effectively detect distortions due to data embedding in a spatial domain. Authors conside the methods based on differences in statistics, which allow to detect changes in the frequency domain, as well as methods based on blind classifiers that can detect the fact of hiding data by most known steganographic methods, as well as determine the lengths of hidden data. Finally authors consider methods for assessing the naturalness of images and applying all discussed steganalysis methods for proposed method. At the end authors give recommendations for the further improvement of thir method.

**V. K. Klochko, V. P. Kuznetsov.** MODELS OF TEMPORAL REGRESSION DEPENDENCIES AND THEIR APPLICATION TO LIVING STANDARD OF POPULATION

Key words: regression equations, temporal dependencies, forecasting, poverty level, incomes of the population.

In traditional statistical analysis, the construction of regression models assumes their stationary nature. In this case, the selection of data for building models does not reflect the time of data reception. The aim of the work is to expand the possibilities of using regression models in forecasting by including time in them. In addition, obtaining a sample of measurements at different points in time in-creases its total volume, which allows solving the problem of small samples when building regression models. The paper proposes two approaches to constructing time regression models. In the first approach, time is included in the system of regression equations along with the data obtained at different points in time. In the second approach, the regression coefficients found independently at different points in time are subject to time processing. As an application, linear regression models of the dependence of poverty level on average population income of the regions of Russian Federation and on the year number were obtained. The model data show a more uniform change in regression dependencies over years compared to a traditional model. The results can be used in Rosstat calculations.

# PHYSICAL ELECTRONICS AND NANOELECTRONICS

**A. A. Fefelov, A. N. Chuvilin.** STUDYING THE INFLUENCE OF THERMOCOUPLE CONTACT HAVING THE SURFACE OF THIN SAMPLE WITH LOW THERMAL CONDUCTIVITY ON TEMPERATURE MEASUREMENT ACCURACY

<u>Key words:</u> temperature measurement, thermocouple, measurement error.

The problem of achievable accuracy for contact method temperature measurements of the samples made of materials used for printed board bases is considered. The aim of the work is to estimate the errors when measuring sample surface temperature caused by the distortion of temperature field, thermocouple probe being in contact with the surface of the object studied. Numerical modeling of temperature distribution in the sample before and after its contact with a thermocouple probe was per-formed; the influence of sample thermal conductivity together with the area of thermocouple contact with the sample on temperature measurement error has been studied. The possibility of increasing the accuracy of temperature measurements by contact method introducing a thermal interface in the form of heat-conducting paste into contact area is considered.