

**MODIFICATION OF A NONPARAMETRIC ALGORITHM OF MODELING
AND DUAL-MODE CONTROL OF MULTIDIMENSIONAL PROCESSES
IN CONDITIONS OF UNCERTAINTY**

E.A. Chzhan, D.A. Kempf

Abstract: the article deals with the problem of the synthesis of control systems of multidimensional processes with several controlled and uncontrolled input variables. The situation of nonparametric uncertainty is considered when the description of the object is unknown. The scheme of nonparametric dual control is defined for two cases. In the first case, the training sample is formed from the first cycles of the system, in the second, there is historical data accumulated during the passive experiment. A data mining unit is included in the control circuit. The block implements an algorithm for determining significant factors in the calculation of control actions. A modification of the nonparametric algorithm for dual control of multidimensional objects under conditions of incomplete data is developed. Expressions are obtained for sequentially calculating the values of control actions. The study of the proposed algorithm was carried out using computer simulation tools. The results of computational experiments on the control of various multidimensional objects of linear and nonlinear structure showed the high efficiency of the proposed approach

Key words: dual control, system, multidimensional process, nonparametric methods, control action

BUILDING A SOFTWARE CODE GENERATOR FOR SOLVING ENGINEERING TASKS

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Abstract: the article presents the results of prototyping a program code generator for streaming data processing, intended for use by engineers of various specialties without programming experience. The framework automatically generates a program according to a visual model compiled by the user, which ensures simplicity and accessibility of independent development of unique automation tools. As a cognitive model for representing the engineering problem, we chose a data flow diagram (Jordan DFD notation), which is widely known, easy to understand, and is in good agreement with the “channels and filters” architecture. This allowed us to develop a web application for the automatic generation of program code with implementation according to the Decorator template. The paper presents a description of the practical implementation of a framework that generates program code based on a user-constructed data flow diagram. The prototype framework created is designed in the style of MVC, supports its own data storage format, is controlled from a browser and can be used to automate data processing for various engineering tasks. The results of the trial operation of the cross-platform software Generator Source Data Flow Diagram Framework are analyzed in detail on the example of calculating the reliability of a computer system. Studies confirmed the flexibility of the developed framework for automating complex structured tasks with a sufficient study of the original model

Key words: program code auto-generation, program development, data flow model, architecture channels and filters

**THE DATA NETWORK BEHAVIOR PREDICTION IN THE MONITORING SYSTEM
OF TELECOMMUNICATION NETWORKS BASED ON THE MODIFIED
KOSARAJU'S ALGORITHM**

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Abstract: the article considers issues of forecasting the behavior of the data transmission network in the monitoring system of telecommunication networks. We analyzed the relevance of the subject area and a set of existing software that solves the problem. We identified the necessary set of functionality, supported by the developed solution, and a list of tasks that will be covered by it, as well as examples of a model of a telecommunication network and tasks that need to be solved during a network tour. We describe a model for storing data in a telecommunications data network. We determined the parameters that will be calculated for each network element, and the dependencies between network nodes. We describe the problem of the presence of a large number of areas of strong connectivity, in connection with which we considered a lot of solution methods and the Kosaraju's algorithm was found to solve the problem. We determined the tasks that were not covered by the Kosaraju's algorithm, and considered options for modifying this algorithm. We constructed a mathematical model that takes into account the time of entry and exit to each element of the network (graph), we described the principles of the relationship between these parameters, and a method for calculating the weight of each area of strong connectivity to determine the necessary bypass route. We described the method for applying the modified Kosaraju's algorithm step by step, summarized the results of the study and described the relevance of the modified Kosaraju's algorithm for other areas

Key words: telecommunications network, prediction, Kosaraju's algorithm, graph, strongly connected component

Radio engineering and communication

DESIGNING PERSPECTIVE ANTENNA ARRAYS WITH A DIAGRAM-FORMING SCHEME BASED ON A ROTMAN PRINTED LENS

**A.V. Ashikhmin, A.V. Ivanov, Yu.G. Pasternak, P.V. Pershin, F.S. Safonov, S.M. Fedorov,
I.A. Zelenin**

Abstract: radio direction finding of radio emission sources (RES) is one of the priority areas of application of radio monitoring systems. The article considers variants of the construction of direction-finding antenna arrays with single-axis beam control with a beam-forming diagram based on a printed Rotman lens and presents the results of their electrodynamic modeling. We propose options for constructing direction-finding antenna arrays with single-axis control of the radiation pattern with chart forming circuit (CFC) based on a printed Rotman lens, and present the results of their electrodynamic modeling. We show the possibility of the integrated design of an ultra-wideband antenna array with switching scanning in the plane of the electric field vector with CFC based on a printed Rotman lens. The most convenient types of emitters for implementation are printed log-periodic antennas and Vivaldi antennas. When using flat vibrators with a common reflector and directors as lattice elements, it is possible to increase the efficiency of the elements in the lattice due to the mutual influence of the emitters in the external field. The considered options for linear antenna arrays, controlled using the Rotman lens, can be used to build antenna arrays with two-axis scanning

Key words: radio direction finding, Rotman lens, Vivaldi antenna

TECHNICAL IMPLEMENTATION OF CRITICAL NODES AND DEVICES FOR RECEIVING BROADBAND RADIO SIGNALS

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Abstract: currently the control channels of all automatic special heavy-class mobile objects (spacecraft, robotic systems, unmanned aerial vehicles, etc.) use broadband radio signals that provide high stealth, interference stability and the ability to ensure continuous operation in a complex interference environment, including unintentional and deliberate radio-electronic impact from an eventual enemy. At the same time, the issue of high-quality reception and subsequent processing of broadband radio signals on the receiving side becomes relevant, which includes the sequential execution of a number of operations (detection, synchronization, entering the tracking mode, demodulation, decoding, etc.). This article is devoted to mathematical and simulation modeling of broadband radio signals, which allows one to determine the required characteristics of signals and conduct a sequential analysis of their reception and processing. MathLab (Simulink) is used as an application software for conducting simulation, which allows us to create a block-by-block scheme and set the required parameters for each block. The paper presents the results of simulation of nodes under noise exposure, which show the need to use robotic complexes and systems of wide-band radio signals in command and telemetry channels, which are easy to process even when the input signal-to-noise ratio (or signal/(interference+noise)) is close to zero, provided that high secrecy and noise immunity are ensured

Key words: broadband radio signals, simulation model, direct extension of the spectrum, device receiving and processing signals, synchronizing in frequency, pseudorandom sequence, demodulator, decoder

PROBLEMS OF PROVIDING RELIABLE RADIO COMMUNICATIONS IN THE NORTH OF RUSSIA

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Abstract: the paper discusses the problems of ensuring reliable radio communications in the Far North of Russia. In the absence of a single type of radio communication that would satisfy northern subscribers at any time and any weather, an integrated approach to organizing communications in the North through the use of medium, short, ultra-short waves and satellite communications is required. We analyzed in sufficient detail the features of the propagation of meter and two-meter VHF waves in the tropospheric layers at an altitude of 0.8-1.5 kilometers. We proposed to solve the problem of communication in the North of Russia in the form of developing a mobile SW-VHFW radio station in the range of 18-150 MHz with a phased array antenna. This range has a number of advantages over others, such as the lowest cost of one kilometer of communication lines, the long range of direct (without relaying) communication and the simplicity of its organization, the high mobility of the radio stations. The frequencies of the range provide direct long-distance single-hop (up to 2000 km) and two-three hop (4000-6000 km) ionospheric communications (18-24 MHz), meteor communication lines (40-60 MHz), SW-VHFW communication within direct radio visibility, as well as direct communication up to 250-400 km through the troposphere at altitudes of 0.8-1.5 km, little dependent on ionospheric disturbances. We present theoretical solutions and experimental results on the characteristics of a phased array antenna of this range. To expand the capabilities of the radio station, we recommend to add to its composition a low-power midrange station with an antenna of the wavelength less than a quarter, and a satellite station

Key words: directional diagram, model, mobile radio station, radio communication, refraction, troposphere, phased array antenna

INTEGRATION OF ANTENNA ARRAY FROM ASYMMETRIC VIBRATORS WITH ROTMAN LENS ON A MULTI-LAYER PRINTED BOARD

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Abstract: radio direction finding and localization of radio emission sources (RES) using unmanned aerial vehicles (UAVs) as a transport base are one of the priority areas for the development of modern radio monitoring systems. The article shows the possibility of implementing a linear antenna array with a flat Rotman lens in the form of a single multilayer printed circuit board. As elements of the array, we used asymmetric vibrators with reflectors and directors, as well as with metamaterial lenses implemented using metallized vias. To suppress surface waves excited in antenna arrays with a significant deviation of the main lobe from the normal, we proposed to use a metamaterial lens consisting of electrically small scatterers located in the aperture of a phased antenna array (PAA). The capacitive impedance introduced by the lens into the radiating aperture of the PAA prevents the propagation of surface waves and improves not only the directional characteristics of the antenna array, but also its input characteristics during wide-angle ultra-wideband scanning. The considered embodiment of the phased array can be used as a sublattice for constructing an antenna system with two-coordinate switching scanning in a frequency band with an overlap factor of more than 2

Key words: Rotman lens, Vivaldi antenna, metamaterials, printed board

DEVELOPMENT AND IMPLEMENTATION OF A SYMMETRIC SELF-ORGANIZING NEURAL NETWORK DECODER

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Abstract: the article presents a new decoder based on a neural network in the form of a symmetrical self-organizing map (SSOM), which can decode any error correction codes. A SSOM decoder is verified by decoding a Low Density Parity Check (LDPC) code. The performance comparison of a SSOM decoder and traditional decoder is performed by simulation. Instead of pre-training the neural network using examples of sets of code words, a decoder using self-organizing cards can be used directly in the communication system. The study of examples of code word sets is the main feature of the decoder, where the characteristic of selective codeword sets is extracted and stored in SSOM in a distributed way. The obtained results show that a SSOM decoder can carry out training and decoding simultaneously, regardless of any encoding rules. A higher probability of the appearance of a code word means a greater probability of correct error correction. Compared to the error correction performance of a conventional decoder, a neural network decoder is easier to implement, it is more flexible and trained for various sets of code words, which has certain prospects for future developments in the communication channel coding system

Key words: neural network decoder, symmetric self-organizing map (SSOM), low density parity check code (LDPC), architecture, implementation

METHOD OF CHOOSING THE OPTIMAL LOCATION OF COMPONENTS ON MULTILAYERED PCBS WITH TAKING INTO ACCOUNT THE EXTERNAL MECHANICAL INFLUENCES

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Abstract: a multilayer printed circuit board (MPCB) is a rather complex design, as it consists of fiberglass composites and a large number of conductive layers. The board provides both the electrical connection of electronic components and their mechanical fastening. When using boards in structures subjected to mechanical loads, the reliability of the MPCB determines the reliability of the entire structure as a whole. To increase the efficiency of the design process, it is required to reduce time and material costs by applying the modeling process and engineering analysis. The article proposes a methodology that differs from the traditional one in a shorter time for finalizing the design by applying modeling. This method of designing printed circuit boards involves two steps. First, vibration analysis of a multilayer printed circuit board with installed components is performed. To check the accuracy of the simulation, the FEM simulation results are compared with the experimental results for the printed circuit board. Comparison of experimental and simulation results shows that they coincide well. The PCB vibration analysis is performed by the FEM method using the lumped weight element, which replaces the actual geometry of the component. The second step is to choose the optimal type of fixing for the printed circuit board, which provides the minimum vibration effect. To achieve this, four types of fixing the sides of the board were studied at the design stage. The boards were analyzed to show mechanical effects using the finite element method (FEM) and engineering analysis (simulation) using Cero Elements / Pro 5.0. An analytical calculation of the behavior of the boards with the same fixing methods was also carried out. The results of modeling comparison and analytical calculation showed good agreement, the difference does not exceed 12%. The natural frequency of the MPCB is

the most critical parameter, showing the possibility of mechanical resonance during operation, and the higher its value, the higher the reliability of the design. The design of the board should have at least a twofold reserve in frequency

Key words: multilayer printed circuit board (MPCB), vibration, radio electronics, design, modeling, CREO

DEVELOPMENT AND RESEARCH OF A LINEAR ANTENNA ARRAY FROM PRINTED LOGO-PERIODIC ANTENNAS, POWERED WITH THE ROTMAN LENS

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Abstract: the important area for the improvement of direction finding phased antenna arrays (PAA) are simultaneous expansion of the band of operating frequencies and operating range of scan angles while maintaining its energy capacity, reliability, dimensions, weight and cost. Among the common options of implementation of antenna elements for PAA, we can note a single dipole antenna, helical antenna, Vivaldi antenna and a patch antenna. Log-periodic dipole antennas (LPDA) are found much less frequently as elements of the PAA. However, LPDA have a definite advantage over other types of antennas: with the correct selection of the parameters of the antenna structure, the operating frequency range of 10:1 or more can easily be achieved while maintaining an almost unchanged directivity characteristic for SWVC (standing wave voltage coefficient) at the input not exceeding 1.5-1.7. We propose LPDA with a range of operating frequencies from 1 GHz to 12 GHz with SWVC less than 2. We show the possibility of realization of a linear antenna array with exciting flat Rappaport lens in ultra-wide bandwidth and scan angle of 90 degrees in the azimuth plane. This variant of realization of the PAA can be used as a sublattice for the construction of the antenna system with the switching two-coordinate scanning in the frequency band with the overlap factor equals to three

Key words: Rappaport lens, log periodic antenna, antenna array

MODELING THE TRANSFER OF DIAGNOSTIC SIGNALS THROUGH A LOADED TRANSMITTER WITH A NONLINEAR TRANSMISSION CHARACTERISTIC

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Abstract: when designing satellite communication lines and calculating their coverage areas, any, even the most unfavorable, combinations of signal propagation conditions should be taken into account, which, when using a repeater, significantly reduces the calculated signal level compared to what is actually provided. In order to ensure electromagnetic compatibility under these conditions, monitoring the compliance of the declared characteristics with the real level of power flux density created by a relay satellite at the earth's surface is the most priority task. The aim of the work in the interests of conducting radio monitoring of satellite communication lines by the active diagnostic method is computer simulation of the transmission of diagnostic (test) phase-code-manipulated signals through a single-signal satellite-relay repeater with a non-linear transfer characteristic that operates in a single-signal mode. The novelty of the presented model is that the diagnostic signal was simulated in relation to the use of phase-code-manipulated signals based on a pseudo-random sequence of maximum length (M-sequence) with the possibility of choosing the degree and type of the generating polynomial. It is shown that after the joint relaying of the test phase-code-manipulated signal and the signal of the satellite communication line at certain ratios of their frequencies, interference of the intermodulation components and the relayed PCM signal will occur, leading to almost complete suppression of the diagnostic signal regardless of its base value. The developed model makes it possible to justify rational requirements for the energy parameters of the diagnostic signals, taking into account the non-linear transfer characteristics of the repeater and to avoid reducing the throughput of the monitored satellite communication line during radio monitoring by active diagnostics

Key words: satellite retransmitter, radio control, satellite communication, diagnosing signals, retransmission path

DECODING LINEAR BLOCK CODES USING NEURAL NETWORKS BASED ON HIGH-ORDER PERSEPTRONS

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Abstract: the article presents a class of neural networks suitable for decoding error correction codes. The neural model is basically a perceptron with a high order polynomial as a discriminant function. One layer of high-order perceptrons is able to decode a binary linear block code with a maximum weight of 2^m in each perceptron, where m is the parity length. For some subclasses of codes, the required number of weights can be much less. The Hamming code (2^m-1 , 2^m-1-m) can be decoded using only the $m+1$ weights in each perceptron. Using genetic algorithms, we obtained efficient $2t+1$ -bit neural decoders for each bit for some cyclic codes and BCH codes (Bovens-Loven-Hockingham), which can be corrected. Using the genetic type search algorithm, we show that for this problem, one can find a suitable set of elements of a high order neural network (in this case, a correcting decoder). We present neural decoders as a set of parity networks at the first level, followed by a linear perceptron at the second level, and thus have simple implementations in a similar VLSI technology

Key words: error correction codes, genetic algorithms, high-order perceptrons, discriminant polynomials

Mechanical engineering and science of machines

CONSTRUCTION OF A SPATIAL MODEL OF A RESIDUAL LAYER DURING POLYGONAL BORING OF THIN-WALLED PARTS

V.V. Kuts, T.A. Tolmacheva

Abstract: the article considers the process of polygonal boring of thin-walled sleeves by a rotating cutter block, and presents a diagram of the formation of the inner hole. We obtained a formula for the cutting surface in the coordinate system of the workpiece outlined by the cutting edges of changeable polyhedral plates (CPP), taking into account all the movements of shaping, in the process of polygonal boring. Based on the results of geometric modeling of the cutting surface and the analysis of the spatial interference of the cutting surfaces formed by the cutting edges of the CPP of the cutting unit, we established a mechanism for the formation of a local area of the residual scallop on the machined hole surface under various processing conditions. We represent the equations of the intersection lines of cutting surfaces forming a local section of the residual scallop, and establish the boundaries of the parameters of these surfaces. We describe a spatial model of the residual layer area in the form of a composite surface. We give a formula that allows us to calculate the maximum height of the residual scallop based on the developed spatial model. We show the simulation results of the residual layer section for the given processing modes, and also the boundary values of the parameters for various sections of the residual scallop. Using the created spatial model of the residual scallop, it becomes possible to investigate the influence of processing modes and geometric parameters of the cutting unit on the quality of the resulting surface

Key words: long thin-walled part, polygon boring, shaping, cutter block, spatial model of the residual layer, residual scallop height

CUTTING MODES OPTIMIZATION TAKING INTO ACCOUNT VIBRATION LEVEL BASED ON APPLICATION OF ARTIFICIAL INTELLIGENCE METHODS

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Abstract: the article considers the problem of cutting modes optimization on the example of turning and milling using artificial intelligence methods. As a criterion of optimality, we propose to use unit costs - a variable part of the cost of processing, which can vary in time units, which ensures optimization in terms of productivity, or in monetary units, which ensures optimization in terms of cost. The calculated optimal values limit the area of rational cutting conditions. In the optimization process using the generalized stochastic model of failures, the variability (spread) of the tool life of cutting tool is taken into account. We propose to search the cutting modes and the preventive maintenance period of the cutting tool using the genetic algorithm. Each considered option of cutting mode is checked for compliance with technical or technological restrictions. In this case, special attention is paid to vibration during the cutting process, the level of which changes as the cutting tool wears out. We propose to evaluate the level of vibration using an artificial neural network in the form of a multilayer perceptron. The considered approach to optimizing the cutting modes and preventive maintenance period of the cutting tool, taking into account the specifics of the cutting process and random factors during wear and destruction of cutting tools, allowed us to propose an adaptive control system for the cutting process taking into account the vibration of the machine part of the technological system. The architecture of the adaptive control system for the cutting process is based on a circuit with a conventional controller controlled by a neural network in the form of a neuro-fuzzy network based on the zero-order Sugeno algorithm. The use of artificial intelligence methods to analyze the vibration level of the machine part of the technological system and optimize the cutting modes and the preventive maintenance period of the cutting tool, allows us to identify reserves for increasing the efficiency of the cutting process, diagnose the condition of the cutting tool during machining and develop an adaptive and robust cutting process control system

Key words: cutting mode, optimization, unit costs, vibration, genetic algorithm, multilayer perceptron, neuro-fuzzy network, adaptive control

STUDY OF THE PARAMETERS OF THE CONTACT INTERACTION OF THE INDENTER WITH THE SURFACE DURING PROCESSING BY METHODS OF SURFACE PLASTIC DEFORMATION

V.P. Fedorov, O.N. Kirillov, M.N. Nagorkin, E.V. Kovaleva

Abstract: The article presents the results of studies of the parameters of the contact interaction of the indenter with the surface when processed by methods of surface plastic deformation (SPD treatment). We considered the methods of surface plastic deformation processing of the outer cylindrical surfaces of samples (steel grade 45) of different hardness by diamond burnishing (indenter – synthetic polycrystalline diamond) and ball burnishing (indenter – ball made of steel grade ShH15) by single-indenter tools of elastic action. We carried out the studies by the method of physical modeling of

processes in the authoring experimental setup. We studied the dependences of the parameters of the contact interaction of indenters with the surface (resistance forces when starting the indenter and in the steady-state processing SPD treatment mode, range of fluctuations in the forces during processing, resistance coefficients when starting the indenter and in steady state, some derived coefficients) on the conditions of SPD treatment: surface pretreatment method, surface roughness after pretreatment, indenter radius, surface hardness, impact forces on the surface of the indenter, processing speed, grease. Experimental studies were conducted according to the method of active experiment. Several processing SPD treatment schemes differed in the sample surface pretreatment method, moving the indenter from a place to various final speeds, indenter materials, the presence of grease on the surface. As a result of statistical processing of the experimental data, we obtained the dependences of the contact interaction parameters on processing factors, which allows us to determine both the variation ranges and the probability of their provision in a given interval depending on the processing SPD treatment factors. Using the developed software, we obtained adequate physical-statistical models for the quantitative assessment of the investigated parameters of contact interaction from specific processing SPD treatment conditions. The main findings of the research are presented in the conclusion

Key words: diamond burnishing, roll burnishing, roughness, indenter, contact interaction, resistance force, plastic deformation

RESEARCH OF THE EFFECT OF PROCESSING MODES ON THE EFFICIENCY OF CLEANING SHEET METAL FOR HOLLOW BALLS FROM SCALE

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Abstract: the article discusses the possibilities of a new simple and effective method of removing scale from the surface of sheet steel intended for the manufacture of hollow balls, as well as the results of the experimental studies. We describe a device for implementing the new method and a mechanism for its interaction with the treated surface. We show the selection of technological factors, such as the angle of inclination of the scalebreaker in the direction of its rotation, the circumferential speed of rotation of the scalebreaker, the force of pressing the tool to the surface to be treated, and the movement of the sample, which have the greatest influence on the main quality parameters of the surface cleared of scale and processing performance. We developed an incomplete factorial experiment plan. In accordance with the developed plan, we carried out experimental studies, as a result of which we obtained the values of the response function for various combinations of factor levels. According to the results of the study, we constructed the dependences of the degree of cleaning of the sheet surface from scale on the main influencing factors and obtained a mathematical model of the process under study in the form of a regression equation, which made it possible to determine the most favorable modes for descaling from rolled metal. The proposed method ensures reliable removal of scale even if it is very firmly fixed to the machined surface of sheet metal

Key words: hollow balls, experimental studies, scale, rolling, processing modes, regression equation, mathematical model