SYNTHESIS OF HIGH-LEVEL SYSTEMS WITH SIGNAL ADAPTATION

S.L. Podvalny, E.M. Vasil'ev

Abstract: the problem of constructing systems with signal adaptation for automatic control of non-stationary objects of a high dynamic order is solved. It is shown that the main difficulty in the synthesis of such systems is the contradiction between the desire to increase the depth of adaptation of the system and the need to ensure its stability over the entire range of non-stationary parameters of the object. A way to overcome this difficulty is proposed, based on correcting the frequency characteristics of the object and using the concept of multi-alternative control, in particular, the principle of separation of functions. As such functions in the problem under consideration, the functions of ensuring the quality of the transient process, adaptation, ensuring system stability and accuracy in steady state are distinguished. A functional diagram of the system has been compiled that ensures separate execution of the listed functions, and the content of the corresponding synthesis procedures has been disclosed. Recommendations are given for choosing the order of the reference model of the transmission coefficient in the feedback circuit of the adaptation loop. The feasibility of determining the parameters of the correction cascade by setting and solving a mathematical programming problem that provides the required stability margins in the system is shown. It is noted that increasing the accuracy of the system by increasing the order of its astatism involves introducing into the system an additional deviation control loop containing an isodrome link. A complete numerical example of the synthesis of a control system is given, and the simulation model demonstrates the achievement of its high adaptive properties while simultaneously ensuring the required reserves of its stability

Key words: non-stationary object, high dynamic order, system stability, explicit linear model, signal adaptation

FREQUENCY REPRESENTATION AS A PROMISING METHOD FOR EVALUATING IMAGE QUALITY

A.A. Nechaev, A.N. Zein, M.A. Orlova, M.A. Durova

Abstract: the task of comparing images and improving the quality of similarity between them is relevant. On the one hand, developers strive to apply different methods of image compression in order to reduce network traffic, and on the other hand, the need for accuracy in recognition and analysis of images from the Internet is increasing. The conducted study reflects the results of the study of reference image quality assessments obtained by calculating average power values in various areas. The subject of the study was the values of objective reference metrics of image quality, the degree of their similarity with expert assessments and ways to bring them closer to expert assessments. The principle of the study is to calculate the characteristics of images and use them as features when using machine learning methods. To implement this task, a program was developed in Delphi in the Embarcadero RAD Studio environment (for converting images into different areas and calculating average power values) and Python scripts using the scikit-learn machine learning library (for training and testing various linear regression models). The results of this study can be used for further research in the field of reference image quality assessment

Key words: discrete cosine transform, image quality, linear regression, machine learning

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COMPUTER GAME VISUALIZATION TOOLS

G.V. Petrukhnova, A.B. Zherelin

Abstract: this article discusses the main stages of visualization of three-dimensional and two-dimensional space in software for creating computer games (game engines). It is shown that game engines are a promising area of work with three-dimensional (3D) graphics. The key user interface development tools are shown. The main stages of visualization are presented and detailed: scene preparation, building a primitive object, coloring objects, creating a projection of screen space, rasterization. It is indicated that Unity offers three different pipelines for creating high-quality visual effects: universal rendering pipeline (URP), high-definition rendering pipeline (HDRP), Built-In. The features and capabilities of these convoys are considered. As a practical example of demonstrating visualization tools, their use for implementing the graphical interface of the "Double tic-tac-toe" application is considered. This game is a complicated version of the classic "tic-tac-toe". The classic version is quite popular among children and young people, but its constant use leads to a gradual fading of interest in the gameplay. In the "Double tic-tac-toe" version, there are additions to the traditional rules, which complicate the gameplay, which allows you to maintain interest in the game. The combined use of the traditional version and the proposed one allows you to make the game multilevel. The "Double Tic-tac-toe" mobile application is made in 2D mode with a side view. The built-in Unity pipeline was chosen as the rendering pipeline. The article discusses the features of the implementation of the graphical interface of this application. The possibilities of the visualization tools of the Unity game engine for the development of the graphical interface of this mobile application are shown

Key words: game engine, 3D scene, visualization, rendering, interpolation, rasterization, Unity, rendering pipeline, URP, HDRP, user interface

NUMERICAL METHOD FOR PASSING THE MATHEMATICAL EXPECTATION OF THE SOLUTION TO THE CAUCHY PROBLEM FOR A DIFFERENTIAL EQUATION WITH A RANDOM PROCESS

G.S. Tikhomirov

Abstract: deterministic and stochastic models are usually used to describe technological processes. The use of stochastic models is preferable, since their use allows us to take into account the influence of uncontrolled disturbances acting on these processes. In this case, random processes are usually described by one of the known distribution laws. The article discusses a numerical method for finding the mathematical expectation of a solution to a second-order ordinary differential equation with initial conditions, one of the coefficients of which is a random process specified by the characteristic functional. The equation cannot be written in the form of an Ito or Stratonovich integral. To obtain a solution to the equation under consideration, it is reduced to a deterministic problem in ordinary and variational derivatives by introducing auxiliary mappings. The solution of the resulting deterministic problem allows us to find the mathematical expectation of the desired function. Since obtaining an analytical solution to the problem in general form is not obvious, it is solved using a grid approximation. An algorithm has been developed that makes it possible to obtain a numerical solution to the mathematical expectation of the desired function at points in the time domain. The proposed method is considered using the example of solving the problem of finding the concentration of radicals in the process of thermomechanical destruction of a polymer. The process model is described by the Riccati equation with a given initial condition, which reduces to a second-order linear inhomogeneous differential equation with a random process. A numerical solution to this model was obtained; analysis of the simulation results showed good agreement between the experimental and calculated values of the concentration of radicals. The simulation results are presented in graphical form. The proposed method is implemented in the form of an application program on a computer

Key words: differential equations with random coefficients, characteristic functional, mathematical expectation, difference method, Gaussian random process, variational derivative, equation with partial and variational derivatives

ANALYSIS OF THE APPLICATION OF PARAMETRIC REWARD FUNCTIONS IN REINFORCEMENT LEARNING ALGORITHMS

V.V. Kashko, S.A. Oleinikova, Yu.S. Akinina

Abstract: the object of study in this article is intelligent walking robots working using reinforcement learning algorithms. In these algorithms, the goal is set through the values of the reward function, the choice of which directly determines the speed and result of learning. Based on the presence of many factors influencing the execution of the agent's actions, the task arises of selecting each parameter included in this function. These parameters are selected based on the best consequences for the agent from the point of view of the decision maker. At the same time, it is necessary to decide on the selection strategy. Based on this, the purpose of the work is to study existing approaches to the formation of the reward function of multifactor systems, identify problems that arise when choosing a "low-quality" reward function, and analyze the use of parametric functions. The study was carried out using a developed application that simulates the action of an intelligent agent based on reinforcement learning with different reward functions. Obtaining experimental data was carried out using the tabular Q-learning algorithm using the example of a simulation of the game "Frozen Lake". All results were obtained using the same algorithm parameters, but with different reward distributions. Thus, an experimental study was conducted that allows us to draw conclusions about the specifics of constructing the reward function. The novelty lies in the development of recommendations to obtain the best reward effect in reinforcement learning algorithms

Key words: reinforcement learning, reward function, parameterization, parametric functions, Q-learning, robotics

MODELING AND ANALYSIS OF SYSTEM STABILITY FOR SOLAR BATTERY ENERGY CONVERSION IN A SPACE STATION

A.K. Tishchenko, E.M. Vasil'ev, A.O. Tishchenko

Abstract: the problem of ensuring the stability of energy conversion systems for solar batteries of space stations is being solved. An analysis of the content of the problem being solved was carried out, and it was noted that in large spacecraft, power supply systems are characterized by the presence of an extensive cable network with inductive reactance, and the presence of a cascade of low-frequency filters, leading to a high dynamic order of the control system. It is indicated that in systems with a shunt converter controlled by a pulse-width modulator, the fundamentally irremovable nonlinearity of its static characteristic of the "saturation" type should be taken into account. A simulation model of the energy conversion system was built taking into account these features. An example of system synthesis based on its simplified linearized model is given, confirming that within the framework of this model it is sufficient to limit ourselves to a regulator with an isodrome link, and at the same time ensure acceptable stability margins. It is shown that if there is a time delay in the system, as well as if there are additional corrective links in the controller, the stability estimates obtained on the linearized model become incorrect, and it is necessary to analyze the system taking into account its nonlinearity. The conditions for the severe occurrence of self-oscillations in a nonlinear system are obtained, their nature is demonstrated, and recommendations are given for the formation of frequency characteristics of the system that exclude the occurrence of these oscillations

Key words: space station, solar battery, shunt converter, pulse-width modulator, stability, self-oscillations

MODELING EVAPORATION DUE TO IR IRRADIATION: EXACT SOLUTION OF ROBIN'S PROBLEM

D.S. Saiko, D.G. Andreev, S.A. Titov, E.Yu. Fursova

Abstract: a model of the heat transfer process under infrared irradiation of a liquid surface is used in the form of solving an inhomogeneous heat conduction equation on a half-line in the case of Newton-Richmann boundary conditions. The heterogeneity is chosen in exponential form. The problem for a semi-infinite medium with boundary conditions of the 1st and 2nd kind was solved earlier in an explicit form with representation through error functions. However, for problems of the 3rd kind, a solution in the form of a Fourier series is usually used, which converges poorly at short times. For this problem, only a general solution in integral form is known. This article presents an explicit form of the solution in the form of a linear combination of error functions, which significantly simplifies the analysis of temperature as a function of time and coordinates in the immediate vicinity of the boundary at short times. By numerical comparison of the obtained solution and the known integral form of the solution from the reference book, it is shown that these solutions coincide. To prove the absence of such results, the literature data on the third boundary value problem for the one-dimensional heat equation was analyzed. The solution will be used when processing the results of experiments on the evaporation of liquid under the influence of infrared radiation.

Key words: one-dimensional heat equation, inhomogeneous equation of parabolic type, third kind boundary condition, Robin problem, analytical solution, exponential inhomogeneity, error function

EXECUTION OF SQL-LIKE QUERIES IN DISTRIBUTED HETEROGENEOUS SYSTEMS BASED ON APACHE HADOOP

A.D. Danilov, M.O. Savvin, A.E. Karachevtsev

Abstract: modern information systems operate with a large amount of heterogeneous data, which must not only be stored, but also recorded at a sufficient speed to keep up with the high rates of new information appearing in numerous primary sources that provide the system with data. The need for fast recording and further storage of incoming data has led to the emergence of a dedicated layer of "raw" data in the structure of big data processing systems, which often have an unstable and heterogeneous structure. Storing such data in classical DBMS in initial volumes is not only inefficient in terms of the cost of a storage unit, but is also often impossible due to the strict structure requirements imposed on the recorded data. To solve these problems, heterogeneous data storage systems were created, which place much lower demands on the quality of recorded information, and sometimes do not check it at all. On the other hand, moving away from relational databases has created the need to use low-level engines to execute queries in their original form. In this article, the authors examined the problem of writing tasks in a distributed Hadoop environment and the existing SQL-On-Hadoop solutions for this. The analysis of SQL-like query translation tools presented in the article demonstrated their advantage in terms of reducing the user's entry threshold, which is achieved while preserving all the advantages of the Hadoop framework, such as replication mechanisms, fault tolerance and parallel task execution in a distributed environment. In conclusion, it is demonstrated what advantages and disadvantages the considered tools have and in which scenarios it is better to give preference to each of them in order to build an effective architecture of the big data processing platform

Key words: big data processing, heterogeneous information, distributed computing, software and hardware

MODELING A MULTISTAGE TECHNOLOGICAL PROCESS IN THE FORM OF A PETRI NET

A.M. Korneev, T.V. Lavrukhina, T.A. Smetannikova, L.K. Erokhin

Abstract: the issues of description of multistage production processes of hierarchical iterative networks and Petri nets are considered. Separate processing stages are represented as cells of an iterative network characterized by a set of inputs, outputs and states. For each cell information coding is performed, alphabets of inputs, outputs and states are formed. The paper considers the hierarchy of cells of a discrete iterative network. The use of Petri nets makes it possible to model the interaction of alphabets of individual factors and to study transitions from one state to another. Combinations of alphabets of considered technological parameters of each cell form Petri net positions corresponding to the described processing stage. In modeling it is possible to present a Petri net, which consists of a set of "layers". Each of them contains its own set of positions and transitions and reflects the completion of one stage and the beginning of the next. Since statistical information is processed, a "layer" should be added, which is responsible for moving from the input data to the data of the first stage, and a similar one - from the second stage to the output values. In general, each "layer" contains information about the next step of the process, where information about the next step of the process is divided into given sets. Each set represents a certain position, where the value reflects the fraction of data corresponding to it. From each position there are arrows to the transitions, indicating sets of statistical data of the next stage of the production process. The number of indicated arrows to each transition corresponds to the number of fixed processes of the corresponding set of the next stage that have passed to the set of the next stage defined by the transition. In the study of complex systems and the choice of methods for their control, functional relations between alphabets of factors and output properties are taken into account. Approaches of modeling complex objects taking into account the hierarchy of cells using iterative networks and Petri nets are described

Key words: Petri net, discrete iterative networks, cell hierarchy, alphabets of factors, cell of iterative chain, Petri net parameters

PARAMETRIC IDENTIFICATION OF TEMPERATURE-INVARIANT VISCOSITY CHARACTERISTICS OF NON-NEWTONIAN MEDIA

A.A. Khvostov, A.A. Zhuravlev, A.V. Ryazhskikh, A.V. Barakov

Annotation: The paper considers the issues of processing and generalization of the results of shear viscometry of non-Newtonian media obtained at different temperatures. The substantiation of the importance of taking into account the influence of shear rate and temperature on the viscosity of liquid-like media in the implementation of hydromechanical, heat and mass transfer processes is given. The object of the study was a model liquid-like biofood medium. The primary results of a full-scale rheological experiment in the form of isothermal dependences of viscosity on the shear rate made it possible to identify an anomaly of viscosity during shear flow and to establish the influence of shear rate and temperature on the change in viscosity of a liquid-like biofood medium during its shear deformation. To approximate the experimental data, the four-parametric Carreau equation was used, taking into account the presence of limiting Newtonian viscosities. Parametric identification of the rheological Carreau model was carried out using the regularization algorithm of A.N. Tikhonov based on a numerical model of the flow of a nonlinear viscous liquid-like medium in the measuring system of a viscometer. It is shown that using the principle of temperature-time analogy (in which the shear rate plays the role of the time factor), it is possible to generalize experimental data into a single temperature-invariant viscosity characteristic. A temperature-invariant representation of the velocity dependence of the viscosity of a liquid biofood medium is achieved by introducing a reduction factor into the Carreau equation, which is a function of temperature. The advantages and practical significance of the analytical description of viscous properties in a form independent of temperature are noted.

Key words: viscosity, non-Newtonian fluid, model Carreau, viscosity anomaly, temperature-time analogy, identification

CLIENT-SERVER ARCHITECTURE OF THE SMART HOME SYSTEM

G.V. Petrukhnova, A.A. Chelnik

Abstract: software development and the use of microcontrollers for a smart home is an actual trend in the field of modern technologies. The article presents an innovative approach to interaction of various devices for a smart home, based on a client-server architecture. This approach ensures the integration of a smart home into a single system, allowing devices to interact and function in a coordinated manner. The key distinguishing features of this approach are the flexibility and adaptability of the software, which allows you to customize the system to different modes, conditions and consumer needs. A comparative analysis of the capabilities of the developed system and the capabilities of the smart home with Alice and the i-Tone system is carried out. The Espressif ESP-32 microcontroller was used as the core of the hardware of the system under development, which has an extensive set of interfaces for connecting to a wide range of external peripherals and low power consumption. The system architecture includes a WEB server based on the Orange PI Zero 3 microcomputer, a router and several ESP-32-based devices. This system has a typical client-server architecture, where the client (smartphone, computer) communicates with a web server, and the server, in turn, interacts with devices. The Message Queuing Telemetry Transport (MQTT) protocol was chosen as the protocol for transmitting data from devices to the server. To manage services in the developed system, containerization using Docker and container orchestration using Docker Compose are used. Eclipse Mosquitto has been selected as the MQTT message broker. To process the received data, a Java Spring Boot service was created, which subscribes to all smart home devices, the server processes the received messages and saves them to the database. Visualization of the received data has been added for the convenience of the user. The web interface is designed using the React library

Key words: smart home, client-server architecture, data exchange, MQTT protocol, ESP-32 microcontroller, Orange PI Zero 3 microcomputer

MODIFIED PATCH ANTENNA BASED ON AN AIR SUBSTRATE WITH A DEDICATED POWER LINE LAYER

A.V. Ashikhmin , E.A. Ishchenko, K.Yu. Pashchenko, S.M. Fedorov

Abstract: the paper considers the design of a directional antenna based on patch radiators with an air substrate. Two antenna designs are considered – when the power line and radiators are made in one layer, as well as a design when the transmission line is transferred to a dedicated (individual) layer. The results obtained show that the use of directional antennas based on patches on an air substrate makes it possible to form highly directional antennas with a high level of matching. The conducted research has shown that the use of an antenna design with isolation of the power line on a dedicated layer makes it possible to improve the characteristics of the antenna: increase the level of matching, expand the range of operating frequencies, improve the characteristics of the radiation pattern, which is especially important in the implementation of noise-proof communication systems with robotic complexes, since a highly directional antenna with a fan pattern is implemented. The antennas considered are designed to operate in the 2.4 GHz frequency range, which is one of the most common and popular for communication systems with unmanned complexes. The considered antenna designs have VSWR in the operating frequency range of less than 2, as well as a KND level of more than 12 dB, which significantly improves the characteristics of the communication channel and increases its noise immunity

Key words: aerial antenna, patch antenna, directional antenna, fan pattern

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THE TECHNIQUE OF NOISE SUPPRESSION IN THE IMAGE OF UNMANNED VEHICLES AIRCRAFT USING THE WAVELET TRANSFORM AND NEURAL NETWORK

M.V. Khoroshailova, A.V. Kuznetsov, A.S. Demikhova

Abstract: this article proposes an improved method for noise reduction of a two-dimensional image based on wavelet transform and a convolutional neural network, which allows suppressing random noise data generated by external or internal factors, reducing the sharpness of images from unmanned aerial vehicles (UAVs). The actual signal differs from the noise after the wavelet transform and the transformed signal serves as input data to the neural network. A deep neural network is used to directly study the noise characteristics in an image associated with the wavelet domain, which allows accurate and adaptive assessment of the noise level and distribution. A convolutional neural network removes noise from a signal using a pure signal, which it uses as a reference as marked data. The resulting noise-carrying images are decomposed using 2D wavelets, ranking the decomposed high-frequency and low-frequency coefficients to form a dataset. The simulation results show that the proposed method provides higher noise reduction performance in terms of peak signal-to-noise ratio and RMS error compared with methods using only neural networks. The analysis of the influence of the number of layers of a convolutional neural network on the efficiency of noise removal by a neural network based on a wavelet transform is presented

Key words: wavelet transform, noise reduction, random noise, two-dimensional image, neural network, high-frequency and low-frequency coefficients

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SOFTWARE AND HARDWARE COMPLEX FOR THE DETECTION AND IDENTIFICATION OF UNMANNED AERIAL VEHICLES

V. D. Martynyuk, D.A. Rybnikov, A.I. Sukachev, E.A. Sukacheva

Abstract: the article presents the development of a software and hardware complex for the detection and identification of unmanned aerial vehicles (UAVs). The paradigm of using such devises is being introduced more and more into all spheres of public life. That is why such software and hardware complexes are necessary to effectively identify the threat that a UAV can provide. The article considers an acoustic method of drone detection, namely the development of a microphone array based on highly sensitive digital microphones of the INMP441 model, combined with the use of artificial intelligence. The use of systems based on the acoustic detection method makes it possible to detect UAVs even in radio silence mode, and with a higher detection rate, unlike radar and radio engineering control methods. The article also discusses the pros and cons of the acoustic control method. To develop the system, we used FPGA (programmable logic integrated circuit) of the ZYNQ 7010 model, microphone array, Qt framework and TCP/IP network protocol. In conclusion, it was revealed that this software and hardware complex allows solving the problem of effective detection of UAVs and is also capable of being integrated into existing large security systems as a separate module

Key words: unmanned aerial vehicle, acoustic detection method, drone identification

Acknowledgments: The work was supported by the Ministry of Science and Higher Education of the Russian Federation (project no. FZGM-2024-0006)

MATCHING SYSTEM OF SHORTENED SHORTWAVE ANTENNA

O.I. Biryukov, N.A. Gilev, Yu.O. Filimonova, K.A. Layko

Abstract: the method of matching of the shortened version of the pin vertical asymmetrical vibrator antenna operating in the short-wave range is considered. The length of the radiating part of the shortened antenna is 0.1 wavelength. The study took place in a relative frequency bandwidth of 20 per cent between 3.6 and 4.4 MHz. The matching was carried out at 4 MHz. The active and reactive parts of the antenna input impedance were measured. An approximation of the input impedance was carried out to build a mathematical model. The approximation of the active part of the wave impedance is described using the pedestal cosine function, the reactive part, which has capacitive character, is described using the hyperbolic function. The use of coaxial cable sections with different wave impedance has been considered in the matching system. The transforming properties of the coaxial cable and a short-circuited loop connected to it in parallel were used as a matching device. The matching was carried out with the wave impedance of the feeder and the receiving and transmitting device of 50 ohms. Optimisation of the initial standard wave impedances of 50- and 75-Ohm coaxial cable was carried out according to the criteria of minimum length and maximum antenna operating frequency bandwidth. Graphs of the standing wave coefficient for different variants of matching systems are plotted. A comparative analysis of the approximation results is carried out.

Key words: asymmetrical vibrator, matching, coaxial cable, wave impedance, short-wave range

ASSESSMENT OF THE EFFECT OF FIXING RACKS ON THE CHARACTERISTICS OF AN AERIAL-BASED ANTENNA

A.V. Ashikhmin, E.A. Ishchenko, S.M. Fedorov

Abstract: the article considers an aerial-based antenna for the implementation of an interference-proof data transmission channel. The antenna in question allows you to provide a fan-shaped radiation pattern, as well as a high level of directional coefficient. Special emphasis is placed on the possibility of fixing the radiating layer above the ground at the required height, since this parameter determines the main characteristics of the antenna. For the implementation of racks, two main approaches were considered, which are based on manufacturing materials – dielectric materials or conductive ones. The conducted research shows that the use of dielectric racks has a minimal effect on the antenna, which allows you to maintain the main indicators. The use of conductive racks can significantly increase the reliability of fixing antenna elements, however, it is worth considering their influence. Studies have shown that the width of such racks has the greatest impact on the characteristics of the antenna. The article describes the characteristics of the antenna both in the ideal case and when using racks. An additional study was conducted for conductive racks in order to determine the effect of their size on the characteristics of the antenna. Thus, the main characteristics of an antenna made of materials that fix the posts were noted, which is relevant and most important when developing antennas based on an airborne substrate

Key words: aerial antenna, patch antenna, directional antenna, fan pattern, antenna mount

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THE TECHNIQUE OF SETTING THE OPTIMAL PARAMETERS OF THE PID CONTROLLER FOR CONTROLLING THE TRAJECTORY OF AN UNMANNED AERIAL VEHICLE USING NEURAL NETWORKS

A.V. Bashkirov, M.V. Khoroshailova, I.V. Sviridova

Abstract: this article presents a technique based on an artificial neural network for configuring optimal parameters of proportional integral derivative (PID) control, which allows to increase the efficiency of controlling the trajectory of unmanned aerial vehicles (UAVs). This system is controlled by three different PID control structures for Roll, Pitch and Yaw movements. Thus, the adaptation of UAVs to linear PID parameters is facilitated by the use of nonlinear behavioral parameters in neural network training. For this purpose, flight simulation of the flying UAV system was performed with 200 different randomly determined combinations of PID parameters in the Mission Planner simulation environment, and a set of location data, both input data and PID parameters when creating the output signal. The simulation performed on the trajectory used as a control when creating the dataset shows that changing the PID parameters of the yaw control does not cause a significant change in the trajectory error. The data set used to adjust the roll and pitch is used for models developed using a forward and backward propagation neural network, which is often used to determine the optimal parameters of PID amplification

Key words: PID control, neural network architecture, roll, pitch, yaw, learning parameters, motion trajectory

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METHODOLOGY FOR OBTAINING AND PROCESSING DATA FROM OPTICAL INSPECTION OF ELECTRONIC COMPONENT TOPOLOGY

M.A. Romashchenko, D.V. Vasilchenko

Abstract: The article discusses one of the stages of a project aimed at developing, manufacturing, and testing a prototype of a software-hardware complex for the optical inspection of electronic component topology. The main task of this stage was to develop a methodology for obtaining and processing optical inspection data necessary for automated quality control of microelectronic products. The necessity of creating such a methodology, which ensures high accuracy and reliability in detecting defects in semiconductor crystals at various stages of quality control, is substantiated. The main requirements for the methodology are formulated, including initial initialization and management of hardware, software configuration, data collection from the machine vision camera, and subsequent processing. The developed structural scheme of the methodology for management, scanning, transmission, and processing of optical inspection data is presented. The stages of obtaining and processing optical images of semiconductor crystals are described, and approaches for integrating software with the hardware part of the software-hardware complex are proposed. The experimental process of collecting and processing images using the industrial inspection microscope Nexcope NX1000 and the digital camera Dahemg imaging MER2-2000-19U3C is described. The algorithm for collecting and preprocessing images to form a training dataset is considered separately. Recommended techniques for preprocessing optical inspection data for their transformation and normalization are listed

Key words: electronic component, machine vision, defectoscopy, optical inspection, non-destructive testing

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INVESTIGATION OF THE DEPENDENCE OF THE MAGNETIC FIELD STRENGTH ON THE SHAPE OF THE SPIRAL OF A PLANAR RADIATOR

N.M. Kalinin, A.I. Sukachev, E.A. Sukacheva, D.A. Rybnikov

Abstract: the article provides an overview of the main shapes of spirals of radiating circuits made using planar technology used in wireless chargers. The use of such emitters makes it possible to simplify the production of wireless charging, reduce its dimensions, and also assemble the emitter on one printed circuit board directly together with the generating circuit. Also, such radiators are much easier to handle and have high resistance to external influences. For the study, emitter models were created in the Altium Designer environment, after which they were analyzed using the finite element method in one of the CST Studio Suite packages. The results obtained made it possible to conduct a comparative analysis of the magnetic fields emitted by planar antennas of all the forms given in the article, among themselves. It is shown that the shape of the spiral plays a key role in the design of such radiating systems. In conclusion, two main points were identified that an engineer should rely on when designing a wireless charger using planar technology, which is important for optimizing the development and production process and improving the efficiency of the final product

Key words: planar antenna, radiating contour, magnetic field

FREE-SPACE OPTICAL COMMUNICATION LINE USING FORWARD ERROR CORRECTION CODING

R.P. Krasnov

Abstract: due to the constant growth in the volume of transmitted data and the high demand for the capacity of subscriber channels, an free space optical communication line (FSO) can act as a “last mile” broadband technology. High spectral and information efficiency compared to radio frequency lines is at the same time deteriorated by atmospheric effects in the communication channel, including atmospheric turbulence. To improve the quality of communication, the joint use of noise-resistant coding and orthogonal frequency division (OFDM) methods has been proposed. The article discusses an OFDM-type atmospheric optical communication system in which binary phase shift keying (BPSK) was used for subcarrier signals. Turbulent atmospheric optical channel was described by a statistical model of exponential Weibull distribution. Convolutional codes, Reed-Solomon codes and turbo codes considered as noise-resistant coding methods. The results show that noise-resistant codes improve the communication quality of the transmission system. It is also shown that turbo codes significantly improve error correction capabilities compared to other methods under the same turbulence and link length conditions

Key words: FSO, bit error rate, OFDM, forward error correction coding

THE ALGORITHM OF THE METHODOLOGY FOR ANALYZING THE DATA OF THE CHARACTERISTICS OF THE NEAR FIELD PRINTED MODULES

V.V. Glotov, N.D. Maikov, D.Yu. Reshetnikov

Abstract: when designing radio-electronic devices taking into account the requirements of electromagnetic compatibility, it is necessary to quickly and efficiently evaluate the electromagnetic model of this electronic device. Typically, this model is based on an equivalent mathematical model. As a rule, errors in solving a mathematical model appear due to errors in physical modeling (geometric approximation) and mathematical modeling. In addition, calculating solutions to Maxwell's equations for large complex problems with minimal error requires time and resources. To overcome the limited computing resources of computers, numerically efficient methods are used that lighten the computational load and are able to approximate the exact solution with minimal error. This article presents an algorithm for analyzing data on the near-field characteristics of printed modules, which is based on equivalent dipole modeling. In the mathematical model, volumetric polarization currents inside the dielectric body are replaced by equivalent dipole moments, which are determined by the fulfillment of the condition of consistency of electric fields inside the dielectric body. The advantage of the developed technique is that it superimposes analytical solutions of the scattered electromagnetic field of canonical structures to simulate the total scattered field of an object of arbitrary shape. These elementary scattered fields are in fact not singular when approaching the distributed source current. They are of the same order as the incident field, that is, first order. As a result, the method does not deviate from the reference values inherent in traditional methods of moment approaches, which are based on Green's function approaches, where a superposition of fields generated by infinitesimal concentrated current sources is performed. In addition, the method is relatively simple to implement, especially because the basis functions for the current are electrically small and therefore can be of low order

Key words: dipole moment, equivalent modeling, magnetic field, near fields, optimization method

LOW-PROFILE DUAL-POLARIZED VIVALDI ANTENNA ARRAY

I.N. Bobkov

Abstract: the planar Vivaldi antenna array designed to operate on two linear polarizations is discussed. The antenna array elements are made of thin dielectric substrate with a copper cladding on both sides and a low relative dielectric permittivity. The excitation of the exponentially tapered slot in the elements is carried out using a transition from a coplanar waveguide to a slot line, and this transition is placed orthogonal to the longitudinal axis of the element at its very base. Such relative arrangement of the parts makes it possible to allocate more useful area of the dielectric substrate for the taper without increasing an overall dimension. The results of a numerical study of the antenna array unit-cell with periodic boundary conditions on the sides are presented. It is shown that broadside voltage standing wave ratio does not exceed 3 in the frequency band with a 2:1 overlap. The studied radiation characteristics show a low level of cross-polarization and the ability to scan the beam at an angle of up to 50º. In this case, the height of the antenna array elements above the metal screen is only half the wavelength at the upper frequency of the operating range and does not exceed the pitch of the antenna array

Key words: antenna arrays, aperture antennas, cross-polarization, wideband antennas, Vivaldi antennas

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INVESTIGATION OF THE DEPENDENCE OF THE DIRECTIONAL COEFFICIENT OF AN AERIAL-BASED ANTENNA ON THE NUMBER OF PATCHES

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Abstract: the article considers an aerial patch-based antenna system for the implementation of an interference-protected communication channel with robotic autonomous complexes. To ensure the most effective interference-free channel, it is necessary to ensure the maximum level of the directional coefficient (KND) and the minimum level of the side lobes (UBL). To determine the characteristics of the antenna, a simulation was carried out of the dependence of the antenna's CND level on the number of emitters forming the antenna array. The results obtained show that the use of an aerial-based antenna to form a highly directional communication system is closely related to the number of emitters used in the antenna array. It has been shown that the use of a linear antenna array makes it possible to form a highly directional antenna system with a fan pattern and a low level of side lobes, while due to the connection between the antenna size and the gain factor, a dilemma arises between the minimum antenna size and the most achievable level of directional coefficient. The simulation results are presented in the form of pictures of directional diagrams, return loss graphs, and also combined into a single table, for ease of analysis of the magnitude of the level of CND, UBL and the width of the main lobes, depending on the number of patch emitters in the antenna system

Key words: aerial antenna, directional coefficient, KND, highly directional antenna

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TECHNICAL CHARACTERISTICS OF A BIFILAR TRANSMISSION LINE IN AN UNDERGROUND QUASI-ONE-DIMENSIONAL STRUCTURE

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Abstract: The paper presents the results of finite element modeling of a two-wire transmission guide line laid along the side surface of a mine working in a continuous semiconducting space of soils and rocks. The dependences of the specific attenuation and the slowing down coefficient of an electromagnetic wave in the range of medium frequencies from 1 to 3 MHz are obtained for different distances between the guide line and the side surface of the tunnel. An approximation of a straight semi-cylindrical tunnel with a radius of 2 m is used, simulating industrial facilities in rocks without metal supports and reinforced concrete walls. As the transmission line approaches the rock, a sharp increase in the specific attenuation occurs. The analytical expressions are presented for calculating the value of the specific attenuation of a radio signal obtained by modeling at medium frequencies from 1 to 3 MHz with a change in the distance between the side surface of the working and the guide line. The variability of the phase of the detected signal and the loss of wave energy along the transmission line are its important technical characteristics in the construction of promising radio and telecommunication systems for communication, navigation, control of autonomous equipment and transmission of information in underground quasi-one-dimensional structures for various purposes.

Key words: transmission line impedance, underground communication, attenuation in mines, velocity factor

OPTIMIZATION OF MATRIX STORAGE USING A MULTI-LEVEL DECODER

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Abstract: A multilevel decoder is proposed for decoding quasi-cyclic low-density multi-edge codes (QC-LDPC) using a graphics processor (GPU) in continuous variable quantum key distribution systems (NPCRCS). Low-density parity codes have excellent error correction characteristics and are widely used in various communication systems. The key limitation that leads to a low decoding rate is due to the fact that successful decoding at a very low signal-to-noise ratio requires a large number of iterations. Therefore, the multilevel Trust Propagation (BP) algorithm is used here to accelerate decoding convergence. However, the decoding bandwidth during postprocessing is one of the main obstacles encountered in a continuous variable quantum key distribution system. Based on this problem, it is proposed to optimize storage methods that are directly related to the parity check matrix. Optimization consists in combining submatrices that have no connections with each other and conducting parallel decoding of a certain number of code words using the GPU. A simulation was carried out to verify the methodology. During the simulation, data were obtained demonstrating that the average speed of the LDPC decoding procedure with three typical code speeds, i.e. 0.15, 0.06 and 0.03, reaches 57.12 Mbit/s, 48.25 Mbit/s and 35.51 Mbit/s, respectively, with simultaneous decoding of 128 code words with a length of 106 without premature completion

Key words: LDPC decoding, quantum key distribution method, trust propagation algorithm, parity check matrix

METHODOLOGY FOR THE DEVELOPMENT AND RESEARCH OF MICROSTRIP FILTERS FOR THE RECEIVER MODULE

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Abstract: this article discusses the creation of a microstrip filter for a receiving device. The development is based on the technology of a microstrip line used as a transmission line for electromagnetic waves in a dielectric medium. Two circuits with different numbers of microstrip elements were created to determine the most suitable material based on electrical characteristics. After the creation and production of the printed circuit board, capacitors and filters were installed on it. As a result, micro-flap filters for the first and second filtration stages were manufactured. The selected dielectric is r4003c and r3003c. The interdigital geometry was used for the first stage filter, and parallel geometry was used for the second stage. Each filter was calculated and modeled in the AWR Microwave Office program. The practical implementation included the formation of gerberas and drawings for the printed circuit board, the manufacture of the board at a third-party enterprise and filling out an order form indicating the basic requirements for the production of the board. In the course of practical implementation, measurements of the dimensions of the conductors and the distances between them were carried out using a microscope, as well as filter tuning frequencies were measured

Key words: microstrip filters, microwave, microstrip lines

DEFINING GEOMETRY SHAPE DISTORTION PARAMETERS OF LOW-RIGIDITYLARGE-SIZED PARTS, TAKING INTO ACCOUNT THE INFLUENCE ON THEMTHE FORCE OF THEIR OWN WEIGHT AND FASTENING CONDITIONS

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Abstract: the issue of developing a methodology for calculating the stress-strain state (SSS) of low-rigid large-sized aircraft parts based on a mathematical model of the finite element method and solving physically and geometrically nonlinear problems in the mechanics of a deformable solid is an urgent problem in the technology of their shaping. The purpose of the research presented in the work is to take into account the deviations of the shapes and sizes of low-rigid large-sized parts obtained during the calculation in the real technological process of shaping this type of parts. A low-rigid double-curvature panel with transverse ribs was chosen as the object of study with which the methodology was developed. Based on the constructed finite element (FE) model, a numerical experiment was carried out. The weight force and fastening conditions were used as the external load acting on the panel. The mathematical model is built using a solution to a static problem. A study of the reliability of the results of numerical calculations was carried out using a curved plate of constant thickness for which there is data from a full-scale experiment. Based on the results of the study of the SSS of the part, it was concluded that distortions of shapes and sizes must be taken into account in the panel manufacturing technology and that their maximum value occurs in the area of the free end of the part. The obtained results of calculating the FE model of the proposed panel allow us to make a transition to the real technological process of shaping, which in turn allows us to control the dimensions of the resulting parts within the tolerance

Key words: double curvature, rolling, radius of curvature, stress-strain state, finite element method, deformable solid, static analysis, gravitational load, shot peen forming (SPF)

IDENTIFICATION OF THE FEATURES OF THE PROCESSES IN THE INTERELECTRODE WORKING VOLUME OF THE ELECTROLYTE FOR METALS PRONE TO PASSIVATION PHENOMENA ON THEIR SURFACE

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Abstract: the purpose of the study is to develop a model complex for controlling the modes of electrochemical dimensional processing for metals made of titanium, aluminum and their alloys: anodic treatment (removal of metal to size with finishing treatment to form an oxide film) and cathodic treatment (coating of the required thickness). Optimization actions to ensure control of processing and supply of the necessary current modes are presented, as well as boundary parameters for regulating changes in temperature fields in the working volume of the electrolyte of the electrode layers of the electrodes and in the interelectrode gap. The temperature parameters influencing the change in the kinetic parameters of the technological process of electrochemical treatment and the components of the dependencies influencing the changes in the parameters of the electrolyte flow modes (concentration components of the working aqueous electrolyte solution: cationic and anionic composition) are established. A physical model has been developed for modeling the rational use of localization of thermal processes in order to cost-effectively apply the specified current supply modes to the working near-electrode zones of the double electric layer. The criteria for the implementation of the technological process of current density distribution over the electrode surface, taking into account the laws of heat and gas release in the volume of the electrolyte, are established

Key words: metal processing, electrolyte, calculation criteria, mechanism of anodic oxidation, working electrodes