CONTENTS AND ABSTRACTS

RADIO ENGINEERING AND COMMUNICATION SYSTEMS

V. T. DMITRIEV, VU HOANG SON. OPTIMIZATION OF ENERGY THRESHOLDS IN WAVELET TRANSFORM FOR SPEECH SIGNAL COMPRESSION BASED ON PARTICLE SWARM OPTIMIZATION

Keywords: discrete wavelet transform, particle swarm optimization, energy-based thresholding, parameter optimization, SegSNR, ViSQOL, speech signals.

An adaptive method for optimizing energy thresholds in discrete wavelet transform (DWT) based on Particle Swarm Optimization (PSO) algorithm for speech signal compression has been proposed and investigated. The method enables automatic selection of optimal energy retention ratios at each level of wavelet decomposition. Optimization is performed to maximize the compression ratio while simultaneously satisfying predefined constraints on the quality of reconstructed speech at a receiver. The quality of reconstructed speech is evaluated using two objective metrics: segmental signal-to-noise ratio (SegSNR) and perceptual speech quality metric ViSQOL. Experimental studies conducted on standard speech signals recorded in accordance with GOST R 50840-95 demonstrate that the method proposed achieves a compression ratio of 87 % while maintaining high reconstruction quality: SegSNR = 9,5 dB and ViSQOL = 3,9 points. According to integral efficiency criterion, the proposed approach outperforms classical methods by 7…14 %.

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YU. N. PARSHIN, V. D. PHAM. NOISE IMMUNITY ANALYSIS OF MIMO SYSTEMS WITH CHANNEL MATRICES CORRELATION

Keywords: channel matrix correlation, space-time matrix, bit error probability, MIMO, number of interference, scatterers, Rice factor.

This paper presents the analysis for the impact of a correlated channel matrix and the number of interference sources on MIMO systems performance. The main aim of the study is to carry out computer simulations of MIMO systems employing space-time coding and increased number of antennas under correlated interference conditions, as well as to identify methods for improving their performance. Bit error probability is evaluated using statistical simulation of the correlating channel matrix coefficients and the number of interference sources. The application of spatial coding in multi-antenna systems is shown to improve interference robustness and the efficiency of channel usage in the presence of concentrated interference. Simulation results confirm that spatial correlation arising from multipath signal propagation leads to significant degradation of information transmission system performance. The obtained results indicate the necessity of taking these factors into account in MIMO systems design, especially under conditions of dense urban environments and limited spatial constraints.

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D. H. NGUYEN, E. P. VASILIEV. ALGORITHM TO CREATE NEURAL NETWORK MODEL BASED ON THE EXAMPLE OF MICROSTRIP MEMS SWITCH

Keywords: circuit and electromagnetic modeling; microstrip MEMS switch; approximation; S-parameters; artificial neural network; neural network model; PIN diode switch.

The algorithm for modeling shunt-type capacitive MEMS switches based on artificial neural net-works is proposed. Modern methods to analyze microstrip devices, including electromagnetic modeling, equivalent circuit models, and machine learning-based models are reviewed. The aim of this work is to develop an algorithm for creating a neural network model to predict S-parameters, providing balance between accuracy and computational time. The algorithm proposed includes stages of design synthesis, training sample generation using Latin Hypercube Sampling (N = 1000 computational ex-periments), electromagnetic modeling in High Frequency Structure Simulator (HFSS) environment via PyAEDT Python library interface, data normalization, and training of multilayer neural network with 16×16×16 architecture. The developed model achieves high approximation accuracy (R^2 = 0,9085 – coefficient of determination, MAPE = 1,15 % – mean absolute percentage error) while reducing computation time by more than 104 times compared to full-wave electromagnetic modeling. Independent test set verification confirms prediction accuracy for resonant frequencies (average error 1,3 –1,4 %) and isolation (average error 2,2 %). The universality of the algorithm is confirmed by additional study on PIN diode switch, achieving R^2 = 0.9684 and MAPE = 2,98 % with N = 975 samples. The proposed approach for approximating frequency-dependent output S-parameters is applicable to a wide class of microstrip switches.

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T. D. LUU, E. P. VASILIEV. ALGORITHM FOR NEURAL NETWORK MODELING OF COUPLED-LINE FILTERS

Keywords: simulation, coupled-line filter, artificial neural network, S-parameters.

This paper discusses an algorithm for modeling coupled-stripline filters (CSL) using artificial neural networks (ANN). The approaches to modeling filters using ANNs are analyzed, focusing on various filter designs and frequency ranges. The aim of this paper is to develop an ANN-based algorithm for modeling and optimizing CSL filters, which significantly reduces design time compared to traditional electrodynamic simulators while maintaining high calculation accuracy.

Input parameters of the model are filter dimensions and electrophysical parameters of substrate, and output parameters are transmission coefficients S21 and reflection coefficients S11. Training database for a neural network model is generated using electrodynamic simulator. A 5-resonator bandpass filter (BPF) based on a coupled-line transistor with center frequency of 16 GHz and a –3 dB bandwidth of 32 % is considered. The developed neural network model demonstrates high accuracy in matching calculation results with electrodynamic simulators, while significantly reducing computational costs.

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E. S. BAGAEV, G. A. FOKIN. INVESTIGATION OF METHODS TO ESTIMATE SIGNAL ARRIVAL TIME IN IEEE 802.11AZ WIRELESS LOCAL AREA NETWORKS

Keywords: wireless local area network, positioning, 802.11az standard, multipath channel, Time-Of-Arrival, super-resolution algorithm.

The work evaluates the accuracy of determining the time of arrival of the ToA signal in wireless local area networks (LAN) of the 802.11az standard for location determination

tasks. The aim of the work is to increase the accuracy of positioning LAN devices indoors. To achieve this goal, the scientific task of investigating the operation of reverse filtering methods and subspaces of MUSIC for ToA evaluation is being solved. The research of the methods is carried out by means of simulation modeling in multipath scenarios according to the standards of the BLS of the TGax group. It is established that for the most optimistic scenario of radio wave propagation conditions, formalized by the model of radio channel A of the TGax group, the minimum COE estimates of ToA are 0,57 and 0,31 ns for the reverse filtering method and the MUSIC subspace method, respectively. The established gain in the accuracy of primary measurements by the MUSIC method serves as a scientific justification for its practical implementation to achieve the set goal.

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MATHEMATIC AND SOFTWARE COMPUTER SYSTEMS AND COMPUTER NETWORKS

D. RAKHMANI, D. I. GRIGORENKO. ENERGY EFFICIENCY OF SQL QUERIES IN POSTGRESQL: EXPERIMENTAL STUDY OF MEASUREMENT AND OPTIMIZATION METHODS

Keywords: energy efficiency, PostgreSQL, RAPL, indexes, caching, parallelism, EDP, measurement methodology.

With the growing energy consumption of data centers, there is an increasing need to optimize database management systems not only for performance but also for energy efficiency. This study aims to develop a reproducible methodology for directly measuring the energy consumption of SQL queries in PostgreSQL using Intel RAPL hardware counters and to experimentally evaluate the impact of indexing, cache state, and parallelism on energy consumption and Energy-Delay Product (EDP) metric. Experiments were conducted on a table containing 10 million records, each test repeated 25 times to ensure statistical reliability. The results show that, at a selectivity of 1 %, index scans reduce energy consumption by 71,9 % and improve EDP by 94,6 % compared to sequential scans. Cache warming reduces the share of energy spent on I/O from 54,9 % to 5,3 %, decreasing total energy consumption from 192,1 J to 68,9 J. The results indicate that the optimal level of parallelism based on EDP metric is achieved with four worker processes; this finding is valid for Intel Core i7-11700 (8-core) configuration. These findings enable practical recommendations for energy-efficient PostgreSQL tuning in high-load environments and lay the groundwork for developing «green» query optimizers that consider both performance and energy costs.

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A. O. FERUBKO, O. D. KAZAKOV. COMPARATIVE STUDY OF LINEAR REGRESSION METHODS TO BUILD ADAPTIVE MANAGEMENT SYSTEM IN HIGH-PERFORMANCE VIRTUALIZATION ENVIRONMENTS

Keywords: RAM, KVM, QEMU, hypervisor, virtualization, hypervisor of the first type, linear regression, regularization, Tikhonov L2-regularization, L1-regularization, weighted linear regression, time series, operating systems, homogeneous systems, machine learning.

The problem of predicting RAM consumption in a virtualized environment based on KVM/QEMU for the purposes of adaptive resource management, RAM in particular, in

a homogeneous system is considered. The aim is to find the main performance indicators of linear regression models for predicting RAM consumption of both guest and host operating systems (OS). The forecast is based on a training sample, which is formed from data on RAM consumption at previous points when the system made a decision on RAM redistribution. The decision-making model is based not on the consumption forecasts themselves, but on the volumes of free (unused) RAM, the value of which is obtained by subtracting from the entire RAM subsystem the RAM that is predicted to be involved in subsystem processes. And based on the forecast of unused RAM, an informed decision about the need and scale of RAM redistribution between subsystems is made. The decision depends not only on forecasts, but also on the size of the window that protects the system from too frequent redistributions in conditions of relatively small difference, as well as on the OS themselves and their restrictions on minimum amount of RAM.

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INTELLIGENT INFORMATION SYSTEMS AND TECHNOLOGIES

L. A. DEMIDOVA, V. V. MASLENNIKOV. ADAPTIVE SELF-TUNING OF GLOBAL PARAMETERS IN TF-QIMOA MULTIOBJECTIVE REAL-VALUED OPTIMIZATION ALGORITHM BASED ON SUCCESS HISTORY OF NONDOMINATED SOLUTIONS

Keywords: multiobjective optimization, quantum-inspired algorithm, thermonuclear fusion, adaptive self-tuning, success history, hypervolume, Pareto front, solution evaluation.

The study presents an adaptive version of quantum-inspired multiobjective real-valued optimization algorithm TF-QIMOA, enhanced with a self-tuning mechanism for global parameters based on success history of nondominated solutions. In contrast to the original TF-QIMOA algorithm which employs fixed global parameter values, a new algorithm, TF-QIMOA-SHA, dynamically adjusts its key control parameters by quantitatively assessing the contribution of each nondominated solution to the evolution of the Pareto front. This assessment integrates three components: hypervolume improvement, temporal stability of solutions, and the degree of exploration of sparsely populated segments of objective space. This approach enables real-time adaptation of search process without any prior assumptions about the structure of objective functions. Experimental validation confirms the superiority of TF-QIMOA-SHA over state-of-the-art multiobjective optimization algorithms, namely TF-QIMOA, QI-NSGA-III, MOWOATS, and MOEA/D-DE-SHA, in terms of solution distribution uniformity along the Pareto front, convergence speed, and the proportion of nondominated solutions relative to previous generation. These results demonstrate high potential of the proposed algorithm for solving complex engineering problems characterized by a high degree of conflict among objective functions.

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L. A. DEMIDOVA, N. A. MOROSHKIN. REFINING CENTROIDS OF VECTOR REPRESENTATIONS OF REGULAR EXPRESSIONS USING HYBRID OPTIMIZATION ALGORITHMS

Keywords: regular expressions, fuzzy clustering, GD, differential evolution, L-SRTDE, L-SHADE-RSP.

The article considers the solution to the problem of clustering vector representations of abstract syntax trees of regular expressions, for the formation of which the BERT model

is used, using standard fuzzy C-means algorithm and its modifications. The main object of the study is hybrid optimization algorithms for the purpose of refining cluster centroids, using one of gradient optimization methods, such as GD, Adam, and RMSProp, in combination with one of evolutionary algorithms, such as classical Differential Evolution (DE) algorithm and its modifications – L-SRTDE and L-SHADE-RSP algorithms. The aim of the study is to determine the feasibility of using hybrid algorithms for optimizing cluster centroids for a standard fuzzy C-means algorithm and its modifications in clustering vector representations of regular expressions, taking into account their structural features. This study provides a comparative analysis of the results of various optimization approaches for refining cluster centroids, using gradient methods and evolutionary algorithms, both individually and as part of a hybrid optimization algorithm. Cluster analysis was performed using vector representations of regular expressions in a 32-dimensional space constructed using UMAP nonlinear dimensionality reduction algorithm. Clustering quality was assessed using a cluster silhouette index. The experimental results confirm the feasibility of using hybrid optimization algorithms that use a combination of gradient methods and evolutionary algorithms for refining cluster centroids for a standard fuzzy C-means algorithm and its modifications. The proposed hybrid optimization algorithms provide more accurate separation of vector representations of regular expressions, which improves the quality of clustering problem solution.

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I. YU. KASHIRIN. DISTINCTIVE FEATURES OF DECIMAL HIERARCHICAL NUMBERS IN LARGE LANGUAGE MODEL EMBEDDINGS INTERPRETATION

Keywords: decimal hierarchical numbers, universal algebras, DistilBERT language models, natural language analysis, ontological taxonomies, semantic similarity.

This paper discusses a new method for analyzing input natural language sentences for LLM language models. A new method is based on the algebra of decimal hierarchical numbers used in algorithms for calculating the semantic similarity of words, phrases, and sentences. The method is suitable for local subject areas and has been tested in "political news" subject area. For this local domain, an OWL ontology and a corresponding graphical representation in the form of a semantic network were develope, with basic entities marked up with decimal hierarchical numbers. A semantic network includes general and application level. A fragment of general ontology is represented by relation, which significantly reduce computational complexity of algebraic operations on knowledge graphs and, consequently, reduce the time required to calculate the semantic similarity of natural language constructs.

Software implementation of the method under consideration uses well-known DistilBERT technology for language neural networks with attentional focus. Knowledge enrichment of pre-trained neural network is achieved by generating new semantic embeddings for words (entities) of natural language sentences and integrating them into a new neural network before fine-tuning in local domain. Training corpora for a new neural network model mIYu-bert v.2.0 were a general corpus from Hugging Face Datasets repository and a local corpus of materials extracted by the author from English-language political articles from international electronic media outlets, including RT, Meduza, CNN, TASS, NYTimes, Bloomberg, and WSJ.

The experimental portion of the material is based on Python v.3 (Anaconda 3) programming language toolkit, LLM DistilBERT, and mIYu-bert v.3.1 software package. The latter toolkit was implemented by the author.

The completed series of experiments allows us to qualify a new method of using decimal hierarchical numbers in the retraining of LLM models for calculating semantic sim-

ilarity as the basis for the technology that is equal in efficiency to currently available international analogues and does not exceed them in computational complexity.
The aim of this paper is to describe a new method to calculate semantic similarity in LLM language models using decimal hierarchical numbers based on OWL ontologies, as well as universal algebras for generating knowledge graphs in local subject areas.
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A. O. KOSTYRENKOV, E. N. MIFTAKHOV. COMPARATIVE ANALYSIS OF ARCHITECTURES OF DECISION SUPPORT SYSTEMS BASED ON RULES, LARGE LANGUAGE MODELS, AND THEIR HYBRID COMBINATIONS

Keywords: Large language models (LLM), hybrid architecture, neuro-symbolic approach, decision support systems (DSS), IoT system.
This paper presents a comparative analysis of three decision support system (DSS) architectures for device control: rule-based, LLM-based, and hybrid (LLM + rules). Particular attention is paid to exploring the balance between the predictability of actions and the security of rules, as well as the flexibility of natural language understanding in large language models (LLM) susceptible to hallucinations and prompt attacks. For comparison, simplified prototypes of all three architectures were implemented, and an experiment was conducted on the same set of Russian-language commands with multiple repetitions. The accuracy of operation, correct execution of valid commands, the justification for rejecting invalid commands, response time, and resilience to wording variability were assessed, allowing us to evaluate the effectiveness of each architecture.
DOI: 10.21667/1995-4565-2026-95-130-142 130

A. K. KLIMENKO, K. A. MAIKOV, V. V. TISHKINA. AUTOMATIC ARCHITECTURE-EXPANSION TRAINING FOR MIXTURE-OF-EXPERTS MODELS

Keywords: mixture of experts, MoE, adaptive training, dynamic architecture expansion.
Mixture-of-Experts (MoE) architectures enable language-model scaling without a proportional increase in computational cost by activating only a subset of parameters per token. Classical approaches, however, fix the number of experts a priori, often yielding sub-optimal capacity and slower convergence. We propose a training method that automatically grows the expert pool during optimization. A new expert is inserted when the validation metric plateaus; a newcomer is initialized via small random perturbation of an existing expert and is warmed-up with increased learning rate. GLUE benchmarks show 5 – 8 % faster convergence versus static-MoE baselines of comparable final size, while theoretical nesting of hypothesis spaces guarantees non-increasing loss. The method provides a theoretically justified opportunity to improve quality characteristics of the solution and to reduce re-source intensity.
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MATHEMATICAL AND COMPUTER MODELING

D. A. PEREPELKIN, A. V. VINICHENKO. DETERMINISTIC MATHEMATICAL MODEL TO FORM MULTIMODAL ROUTE PACKAGES IN TRANSPORT NETWORKS

Keywords: multimodal transport network, multimodal passenger transportation, multimodal route package, transport segment, mathematical model, multi-objective optimization, Pareto optimality.

The paper considers the problem of forming route packages in multimodal transport networks (MTNs) under conflicting optimality criteria. A deterministic mathematical model is proposed, based on MTN graph representation and vector-valued objective function that includes cost-related, time-related, and structural characteristics of routes. To analyze trade-off solutions, a Pareto-based multi-objective optimization approach is employed. Computational modeling and visualization of Pareto fronts are performed, making it possible to analyze the influence of constraints and penalty functions on the set of feasible solutions. The obtained results confirm the correctness of the proposed model and its applicability for decision support in MTNs.

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SYSTEM ANALYSIS, MANAGEMENT AND INFORMATION PROCESSING

S. V. SKVORTSOV, V. I. KHRYUKIN, T. S. SKVORTSOVA. MODEL DEVELOPMENT OF DIGITAL VARIABLE STRUCTURE SYSTEM TAKING INTO ACCOUNT CONTROL OBJECT STATE DETERMINATION FEATURES

Keywords: variable structure system, control object, structure switching hyperplane, state space, phase coordinates vector, sliding mode, finite differences, continuous differences, digital controller.

The problem of developing a model of a digital variable structure system that takes into account the specifics of determining the state of the control object is considered. The aim of the work is to analyze the impact of error signal discretization and the method of obtaining information about the object's coordinates on the stability of the control system. It is proposed to investigate the dynamics of a digital variable structure system in the phase space of a continuous system, which makes it possible to use its mathematical model to describe the dynamics of a control object with a digital controller. Analytical expressions are obtained for determining the positions of the switching hyperplanes in the phase space, which allow for the justification of the choice of the allowable area of stable motion of the system in the quasi-sliding mode. The experimental part of the work shows an example of calculating the parameters of digital control device for the object described by second-order differential equation which confirms the possibility of practical use of the developed model.

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O. V. MELNIK, S. I. BABAEV, M. N. SARAEV. ACOUSTIC DESCRIPTORS OF HARMONIC SPEECH STRUCTURE FOR EMOTION ASSESSMENT

Keywords: speech harmonics, HNR method, Fundamental Frequency estimation, Jitter, Shimmer, STFT analysis, Formant Analysis, Cepstral Analysis, emotion assessment, stress.

The article presents classical acoustic descriptors based on the harmonic structure of speech used for automatic assessment of emotional states (neutral state – stress). The aim of the work is to systematize methods for analyzing the harmonic structure of speech, reveal their physiological basis and assess their informativeness with respect to emotional changes. Key methods are considered: analysis of harmonic-to-noise ratio (HNR), estimation of fundamental frequency (F0), parameters characterizing instability of period and amplitude (Jitter and Shimmer), spectral analysis based on short-time Fourier transform (STFT), cepstral analysis and formant analysis. Their extraction algorithms and sensitivity to emotional changes are described. Particular emphasis is placed on physiologically interpretable parameters (F0, HNR, Jitter and Shimmer) and on the fundamental methods underlying their calculation - spectral and cepstral analysis. The limitations of each method are highlighted, and recommendations for selecting descriptors are provided. The practical significance of the methods discussed lies in demonstrating their applicability on illustrative material: in a paired comparison (neutral – stress) characteristic changes were observed – a decrease in HNR, increases in Jitter and Shimmer, an increase in signal energy (MFCC0), and greater formant variability (F1 – F4). This confirms the sensitivity of the descriptors to emotional stress and supports the use of a combined feature set. The article will be useful to specialists in signal processing, psycholinguistics and emotion recognition systems.

DOI: 10.21667/1995-4565-2026-95-171-185 171

V. G. ANDREYEV, V. A. BELOKUROV, N. V. BELOKUROVA. APPLICATION OF VECTOR AUTOREGRESSIVE MODEL FOR SPECTRAL ANALYSIS OF ENCEPHALOGRAMS

Keywords: electroencephalogram, alpha rhythm, non-stationarity, power spectral density, vector autoregressive model, estimation of power spectral density of a random process.

The problem of estimating spectral power density of biological signals is considered. A vector autoregressive model for estimating spectral power density is proposed. The criterion of minimum first autocorrelation coefficient at the output of whitening filter is proposed for estimating model order. The aim of the work is to investigate the feasibility of calculating spectral power density of encephalogram signals using a vector autoregressive model. The authors show that model order depends not only on the number of encephalogram leads used, but also on the location of the leads on the head. A relationship between the order of selected vector autoregression model and the magnitude of autocorrelation coefficients of whitening process is found. The effect of an increase in the number of signals from leads on the order of selected model is considered. The model order is shown to lie in the range from 5 to 14 for the number of leads used from 4 to 12. The proposed algorithm is tested using real EEG data.

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A. S. VENDIN, S. A. LARYUKOV. NEURAL NETWORK FLOOD DETECTION TECHNOLOGIES BASED ON DATA FROM SENTINEL-2 SPACECRAFT

Keywords: convolutional neural networks, machine learning, water bodies segmentation, automatic flood detection, Earth remote sensing data processing.

The problem of flood segmentation and water body detection based on satellite imagery from Sentinel-2 mission is considered. The aim of this work is to develop automated software tools that allow for automatic and accurate monitoring of water bodies using remote sensing data and artificial intelligence methods. The paper analyzes known approaches to solving this problem and identifies their shortcomings, which explains the relevance of new research in this area. Due to limited applicability of existing methods, as well as low quality of labeling in public datasets, a neural network based on «Lanky U-Net» architecture and trained on manually annotated dataset is proposed. As a result of the research, the following objectives were addressed: preparation and labeling of multispectral images obtained from Sentinel-2 satellites showing flooded areas in Russian regions; training a model for water body detection; evaluating model performance using accuracy, precision, recall, and loss values; and flood detection using a static water body mask. Numerical indicators of segmentation quality and experimental results are presented, demonstrating the effectiveness of the proposed approach.

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L. L. KUZNETSOV. ALGORITHM TO IMPROVE ACCURACY OF RADAR IMAGE OBJECTS CLASSIFICATION BY CRITERION OF BELONGING TO WATER SURFACE OR LAND USING DIGITAL ELEVATION MODEL

Keywords: Earth remote sensing, radar images, digital elevation model, objects classification, water surface detection.

The article suggests an algorithm that allows to improve accuracy of radar image objects classification by criterion of belonging to water surface or land based on combining the results of primary classification with a class mask generated from digital elevation model (DEM) data. The main task is to create an algorithm that generates a class mask by analyzing relative height of surface objects. This work is relevant due to the need to create and improve radar image objects classification algorithms to solve the tasks of Earth remote sensing (ERS) systems. The results of the proposed algorithm utilization showed a high degree of elimination of false shadow mountain slopes classification into water surface class and are quantified at up to 21,7 square kilometers of correctly classified Earth surface area..

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A. A. DENISOV, A. I. NOVIKOV. CORRELATION-BASED METHOD FOR SYMMETRIC REFINEMENT OF KEYPOINT COORDINATES

Keywords: keypoint, detector, keypoint descriptor, correlation coefficient, keypoint neighborhood analysis, matching accuracy.

In keypoint-based image alignment, not only is the correctness of point matching critical during the correspondence stage, but also the accuracy of keypoint coordinate localization itself. The analysis of cross-correlation values between matched keypoints has shown that conventional detectors often localize keypoints with slight deviations. These localization errors are typically small – around 1–2 pixels along one or both image axes;

but the resulting differences in patch-wise correlation coefficients between incorrectly and correctly located points can range from 0.6 to 0.9. The aim of this study is to demonstrate that popular keypoint detectors may introduce such shifts and to present a method for refining keypoint positions. The proposed approach, a correlation-based symmetric refinement method, evaluates zero-mean normalized cross-correlation (ZNCC) across all possible pairs of points within neighborhoods surrounding initially matched keypoints. Unlike conventional methods that refine only one point, the proposed technique simultaneously adjusts both keypoints in a matched pair. The experiments conducted on real-world imagery show that the method yields a substantial improvement in overall matching quality. The proposed method can be applied in computer vision systems where high-precision image matching is critical-such as mapping, aerial imaging, medical visualization, robotics, and in tasks involving the fusion of images captured from different viewpoints and sensors.

DOI: 10.21667/1995-4565-2026-95-215-225 215

I. P. BURUKINA, G. O. FELDMAN, D. A. GRISHAEV. MULTIMODAL SYSTEM FOR AUDIOVISUAL DECISION SUPPORT FOR VISUALLY IMPAIRED USERS

Keywords: system, visual impairment, segmentation, neural network, spatial orientation, testing, efficiency.

The work is devoted to solving the problem of spatial orientation of persons with visual impairment. The aim of the research is to develop a multimodal system that combines image segmentation algorithms and neural network methods to transform visual signals into a detailed audio representation of surrounding space. The system has successfully passed comprehensive technical testing, showing high functional and operational characteristics. The main advantages are high accuracy of object recognition, reliable distance detection, quick response and low power consumption. The research plays an important role in the development of domestic rehabilitation technologies aimed at ensuring accessibility of infrastructure and increasing the independence of people with visual impairment.

DOI: 10.21667/1995-4565-2026-95-226-235 226

A. V. GUBAREV, S. V. GUBAREVA, A.N. SAVICHEVA. ORGANIZATION OF WORKS TO IMPROVE TECHNICAL SYSTEM RELIABILITY

Keywords: technical system reliability, algorithm for improving reliability, interaction scheme, product quality, technical system failure, operating mode map, reliability program, design documentation.

An integrated approach to the organization of work to improve the reliability of complex technical systems is considered. The aim of the work is to develop an algorithm for organizing work to improve the reliability of technical system. Special attention in the study is paid to the fundamental role of systematic collection, processing and analysis of primary information about failures and malfunctions during the warranty period. The sources of this information, as well as the requirements for it, are considered in detail. The authors emphasize that it is this analytical base that serves as the basis for identifying design weaknesses, limiting elements, and underlying causes of reduced reliability. As a practical tool, the article offers a detailed algorithm for organizing work to improve reliability. For the effective implementation of the process for technical system reliability increase, a scheme of interaction between the divisions of enterprise is proposed, a reliability group that coordinates the efforts of all participants being the center of it.

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BIOMEDICAL INFORMATION SYSTEMS

M. S. GALUSHKA, V. YU. VISHNEVETSKIY. MODELING OF NEUROFEEDBACK TRAINING SYSTEM BASED ON PORTABLE EEG FOR REHABILITATION OF PATIENTS WITH POST-TRAUMATIC STRESS DISORDER

Keywords: post-traumatic stress disorder, biofeedback, electroencephalography, portable devices, neurofeedback, signal processing, control system, adaptive algorithm, rehabilitation.

The aim of this work is to develop and formally describe mathematical and structural models of key components for a biofeedback (BFB) system based on portable electroencephalography (EEG) for the rehabilitation of patients with post-traumatic stress disorder (PTSD). The relevance of the study is due to the growing prevalence of PTSD and the need to create personalized, accessible, and effective methods for its correction. The article addresses the tasks of modeling the process for selecting an initial neurofeedback training protocol based on the integration of clinical and EEG data, an algorithm for processing single-channel EEG signals to extract relevant neurophysiological markers, and a biocontrol loop that implements neurofeedback. A protocol selection model based on a production rule system, considering patient's clinical profile (determined by PCL-5) and EEG patterns (identified from individual resting-state recordings), is presented. A detailed model for EEG signal processing is provided, including preprocessing stages (band-pass and notch filtering, artifact detection and rejection), spectral analysis using Welch's method, and calculation of power characteristics for alpha, beta, and theta rhythms. A structural and functional model of neurofeedback training loop is developed, describing the interaction between a patient and hardware-software complex, as well as threshold adaptation algorithms based on target performance. The obtained models create a theoretical basis for the development of algorithmic and software solutions for personalized BFB systems for PTSD treatment, providing a formalized description of their functioning and the possibility for further verification and optimization. The modeling results can be used in creating software for portable EEG devices aimed at improving the psycho-emotional state of patients with PTSD.

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PHYSICAL ELECTRONICS AND NANOELECTRONICS

B. A. KOZLOV, E A. KOZLOV, D. S. MAKHANKO. PHOTOELECTRON DYNAMICS AT PRE-IONIZATION STAGE IN SEALED-OFF TEA-CO_2 LASERS

Keywords: TEA-CO_2 laser, volume discharge, pumping, preliminary ionization, plasma-chemical reactions, concentration and lifetime of photoelectrons.

Quantitative information was obtained on photoelectron dynamics during pre-ionization stage in a sealed TEA-CO_2 laser, the working mixtures of which contain products of plasma-chemical reactions. The authors established that the decrease in photoelectron concentration during pre-ionization stage by several orders of magnitude is due to the attenuation of ionizing radiation intensity by secondary compounds formed in laser's active medium under the influence of plasma-chemical reactions. A mechanism for localizing a nanosecond volume discharge which limits pulse repetition rate and average power of laser radiation was substantiated.

DOI: 10.21667/1995-4565-2026-95-255-262 255

B. A. KOZLOV, E A. KOZLOV, D. S. MAKHANKO. ANALYSIS OF PUMP DISCHARGE PLASMA MACROINHOMOGENEITIES INFLUENCE ON THE LIMITATIONS OF TEA-CO2 LASER AVERAGE RADIATION POWER

Keywords: TEA CO_2-laser, pumping, volume discharge, preionization, plasma macro-nonuniformities, volume discharge localization, pulse repetition frequency, average radiation power

When TEA-CO_2 lasers are excited at pulse repetition frequencies exceeding 300 – 500 Hz, the zones with increased glow brightness – plasma «macro-nonuniformities» are formed in the discharge gap. Their formation initiates the transformation of pump volume discharge into a high-current local discharge and the breakdown of laser radiation generation. Eliminating plasma macro-nonuniformities enables an increase in pulse repetition frequency by 1,5 – 2 times and in average radiation power level by 1,3 times..

DOI: 10.21667/1995-4565-2026-95-263-269 263

V. A. SOKURENKO, YU. V. SAKHAROV, P. E. TROYAN. STUDY OF CHARGE TRANSFER WITH MOTT MODEL USING LOW-FREQUENCY NOISE DATA

Keywords: low-frequency noise, current-voltage characteristics, Mott transitions, activation energy, electrical conductivity, diagnostics.

In this work, the electrical conductivity of a carbon resistive film was investigated by means of a combined analysis of current–voltage characteristics and low-frequency 1/f noise characteristics in Mott coordinates within temperature range from –150 °C to +110 °C, at fixed voltage of 3 V, and in frequency bands Δf: 0.5 Hz – 10 Hz; 0.5 Hz – 1 kHz; 0.5 Hz – 10 kHz. The aim of the study is to refine a conductivity model and to assess the potential of noise analysis as a tool for diagnostics and reliability prediction of resistive elements. The author have shown that noise measurement frequency range significantly affects the identified charge transport mechanism: from nearest neighbor hopping at low frequencies (n = 1) to classical two-dimensional and three-dimensional variable-range hopping regimes at higher frequencies (n = 3 – 4). The obtained results make it possible to refine the electrical conductivity model of the material studied and confirm high informativeness of noise analysis for the diagnostics of structural features. The analysis results can be applied to the prediction of resistive elements reliability.

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