CONTENTS AND ABSTRACTS

RADIO ENGINEERING AND COMMUNICATION SYSTEMS

V. I. KOSHELEV, V. A. RAMAZANOVA. ANALYSIS OF INTERFERENCE SUPPRESSION EFFECTIVENESS FROM HYDROMETEORS AND UNDERLYING SURFACE IN ONBOARD RADAR SYSTEMS

Keywords: reflection spectrum, clutter from the underlying surface, power spectral density, multi-channel filtering.

A comparative analysis of efficiency has been carried out according to the criteria of passive clutter rejection and signal-to-(clutter+noise) ratio improvement factor in filtering systems comprising single-channel or multi-channel filters. The paper presents structural diagrams of filtering and corresponding dependence plots for various filter structures and orders, as well as for the parameters of passive clutter and uncorrelated noise at the input of primary signal processing system. The aim of the work is a comparative analysis of the efficiency of passive clutter rejection of various origins in primary signal processing systems of single-channel and multi-channel structure.

DOI: 10.21667/1995-4565-2026-97-3-10 3

M. V. GRACHEV, E. V. VASILYEV. ANALYSIS OF IONOSPHERIC INFLUENCE ON THE OPERATION OF SATELLITE – GROUND RADIO TELESCOPE COMMUNICATION CHANNEL

Keywords: ionosphere, radio wave propagation, ground-based radio telescope, satellite, layered model, channel coefficients.

The paper considers the problem of analyzing the characteristics of the radio channel used for transmitting a calibration signal in a system consisting of a satellite radio transmitter and a ground-based meter-wave radio telescope with several separate receiving sites. The aim is to identify the properties of the ionosphere from the standpoint of its interfering effect during amplitude and phase calibration of the phased antenna array of the radio telescope. The ionosphere is represented by a model consisting of a large number of thin layers, within each of which the dielectric permittivity can be assumed constant. Based on this model, the coefficients of the SIMO system channel matrix are calculated, and the influence of the ionosphere on the accuracy of amplitude and phase calibration of the radio telescope receiving system is evaluated. It is concluded that such calibration using the signal of a satellite radio transmitter is feasible, provided that distortions introduced by the ionosphere are обязательно taken into account.

DOI: 10.21667/1995-4565-2026-97-11-19 11

V. T. DMITRIEV, VU HOANG SON. COMPUTATIONAL COMPLEXITY OF MULTIRATE SIGNAL PROCESSING SYSTEMS BASED ON THE KHURGIN – YAKOVLEV REPRESENTATION

Keywords: multirate signal processing, Khurgin – Yakovlev representation, computational complexity, discrete differentiation, Cooley – Tukey FFT.

The problem of analytical estimation of the computational complexity of multirate signal processing systems based on the Khurgin – Yakovlev representation is considered. A discrete differentiation operator in frequency domain is proposed, enabling a single

computation of shared spectrum for all K channels and reducing the cost of each additional channel. Closed-form analytical expressions are derived for the number of real arithmetic operations in analysis and synthesis blocks for arbitrary numbers of channels K, decomposition stages P, and frame length M. A normalized efficiency metric is introduced that compares the total computational cost of the Khurgin – Yakovlev system against that of an equivalent number of independent Kotelnikov systems. The authors show that for KP ≥ 3 channels the Khurgin – Yakovlev system is consistently cheaper: the best result is 64 channels at a cost 8,9 times lower than that of 64 independent systems. The formulas are numerically verified for eight configurations. A comparative analysis of four classes of embedded platforms shows that the computational load does not exceed 0,51 %, confirming full real-time feasibility of the system..

DOI: 10.21667/1995-4565-2026-97-20-30 20

V. T. DMITRIEV, M. S. BUNIN. DEVELOPMENT OF ALGORITHMS FOR SPEECH PAUSE IDENTIFICATION FOR INTELLIGENT COMMUNICATION SYSTEMS

Keywords: speech signal, acoustic interference, quality of reconstructed speech, pause detection algorithm, voice activity detector.

This paper proposes the algorithms for detecting pauses in speech signals in complex noise environments. The aim of the paper is to develop algorithms for detecting pause boundaries that ensure precise de-termination of their position in a speech signal. Main known criteria for detecting pauses are analyzed and the most robust criteria are identified. A comprehensive algorithm for detecting pauses in a speech signal is proposed based on a combination of most noise-resistant speech parameters. An algorithm for precise pause detection is proposed, allowing for the precise determination of pause's position in a speech signal, significantly improving reconstructed speech quality at transmission system output.

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E. A. ZHIRKOV. CORRECTION OF MONOCULAR VISUAL ODOMETER READINGS WHEN FLYING OVER TERRAIN AREAS BEING NOT UNIFORM IN HEIGHT

Keywords: autonomous navigation, visual odometer, unmanned aerial vehicle, barometric altimeter, laser altimeter, computational experiment, change-point problem.

The problem of autonomous navigation of a low-altitude unmanned aerial vehicle based on monocular visual inertial odometry in the absence of a signal from radio navigation satellite systems and active guidance devices is considered. Special attention is paid to flight scenarios in areas with limited or no satellite navigation, including urban canyons, woodlands, and mountainous areas. The aim of work is to estimate error and improve the accuracy of monocular visually inertial odometer when flying over terrain that is not uniform in height using information from a laser measuring channel that complements a barometric measuring channel of a complex altimeter. Based on the results of flight tests over flat landscape area, a positioning error was estimated without auxiliary channel for measuring the distance from the camera to terrain elements. The results of a posteriori correction of aircraft trajectory are presented, taking into account the correction for terrain areas that are not uniform in height, which made it possible to verify the effectiveness of proposed approach to correcting navigation data.

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D. K. PROSKURIN, E. A. ISHCHENKO, YU. G. PASTERNAK, A. P. TIKHONOV, S. M. FEDOROV. AN ANTENNA BASED ON A RADIAL WAVEGUIDE FOR GENERATING RADIATION WITH ORBITAL ANGULAR MOMENTUM

Keywords: radial waveguide, vortex waves, helical antenna, orbital angular momentum, OAM.

This article presents the design of an antenna that generates vortex waves or waves with orbital angular momentum using an excitation system implemented on a radial waveguide and circularly polarized helical radiators. The aim of the study is to investigate the feasibility of implementing an antenna that generates vortex waves or waves with orbital angular momentum using a radial waveguide and helical radiators that provide the required phase shift. The excitation system ensures in-phase, equal-amplitude, and highly efficient excitation of radiating antennas, while the use of circularly polarized antennas enables the phase shift necessary to excite vortex waves by rotating the antenna around its axis by an angle equal to the desired phase distribution. The results of the study are demonstrated by phase patterns of the resulting vortex waves, excitation system characteristics, and circularly polarized antenna. The resulting antenna system allows for the formation of vortex waves of the first two modes with subsequent highly efficient radiation, which is caused by minimal losses in excitation system – a structure based on a radial waveguide.

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MATHEMATIC AND SOFTWARE COMPUTER SYSTEMS AND COMPUTER NETWORKS

P. V. GORSHKOV, I. A. BESSMERTNY. A LIFECYCLE TECHNOLOGY FOR AI-ASSISTED SOFTWARE PRODUCT DEVELOPMENT WITH REQUIREMENTS TRACEABILITY CONTROL

Keywords: IT project management, software lifecycle, large language models, requirements traceability, AI-assisted development, prompt-oriented task statement, decision observability, task decomposition, small development teams.

Language models speed up development, yet delivery stability declines: the bottleneck has moved from writing code to verifying the result. The aim is to improve the manageability of the lifecycle of software products built by small teams with language models through a technology where every transition between stages is recorded as an artifact and the chain «requirement – model task – artifact – verification» is controlled by a measurable indicator. The objectives are to formalize traceability and introduce indicators of coverage and decision observability, to define the condition for passing between stages, to build a model of expected losses from traceability gaps, to estimate the rational task size per model call, and to verify the technology experimentally. A traceability graph and two indicators are proposed: coverage, which sets the condition for passing between stages, and decision observability. A controlled experiment was carried out: four modes, three independent runs each, a reference suite of 45 acceptance tests, and comparison of runs on 300 random in-puts; a separate series on extended specification was checked against control implementation on 500 inputs. Given a complete specification, both modes yield 100 % of passed tests regardless of form and size of the statement. With incomplete statement the share of passed tests falls to 43,0 % and requirements implementation completeness to 11,9 %. The technology does not improve gen-

eration, but increases decision observability from 11,9 to 92,9 % and surfaces on average 27.7 assumptions per run requiring agreement with the customer. The loss model gives a 5- to 10-fold reduction of the expected cost of resolving specification gaps.
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P. S. BABKIN. CLASSIFICATION OF DRAM ERROR

Keywords: DRAM memory, memory cell errors, addressing errors, mutual influence between memory cells, classification, memory error models, algorithms.

Over the past 15 years, reliability monitoring tools have evolved significantly alongside DRAM memory development. A wide range of error detection and correction tools has emerged, significantly reducing the risk of latent failures and system downtime. The aim of this paper is to analyze and classify error types in random-access memory. There are two types of memory errors: transient errors, caused by transmission errors or «spontaneous» charge changes, and permanent errors (defects), caused by a faulty memory region and consistently generating read errors when accessing these regions. Statistically, approximately 90 % of memory errors are caused by a row defect [1], which is why DDR4 DIMM standard (JEDEC JESD79-4B) requires at least one spare row per bank group. Examples of the most common functional faults are provided.
DOI: 10.21667/1995-4565-2026-97-69-83 69

A. Y. CHISTYAKOV, M. A. ZAPLETINA. METHOD FOR COMPENSATING ACCUMULATED INVERSIONS AFTER ROUTING STAGE ON FPGA

Keywords: field-programmable gate array, FPGA, computer-aided design, routing, inversion compensation.

The design based on field-programmable gate arrays is becoming increasingly widespread for prototyping custom circuits, organizing telecommunication systems and communication networks, for aviation, space, automotive, and other applications. In response to growing demand and the specifics of target application areas, new architectures of this class of chips are being developed, enabling improved design characteristics under existing mass production processes. The use of existing software and algorithmic solutions for circuit design based on these architectures is complicated due to the impossibility of accounting for all features of their circuitry. In particular, the problem of preserving correct signal levels after the routing stage is relevant for FPGAs whose switching resource structure does not guarantee this automatically. Existing routing algorithms do not address this problem; therefore, the aim of this work is to formulate and implement, within the existing X CAD tool, a method for compensating inversions accumulated during routing. Experimental evaluation on a set of test circuits for FPGAs 5510XC3AT, 5510TC028, and 1931BA018 demonstrated the feasibility of bringing signal levels to the design values for all solvable cases.
DOI: 10.21667/1995-4565-2026-97-84-91 84

N. A. DUKSIN. MANAGING PROJECT CONSTRAINTS AT PLACEMENT AND ROUTING STAGES OF FPGA PROGRAMMABLE COMPUTERS

Keywords: soft-processor, cluster computing systems, FPGA, RTL, design constraints.

This work addresses the problem of managing design constraints during the placement and routing stages in order to improve the efficiency of hardware implementation of programmable computers based on field-programmable gate arrays (FPGAs). The primary

aim of the study is to develop and investigate an approach for defining project constraints for FPGA-based programmable computers, aimed at increasing the achievable clock frequency and enhancing the overall efficiency of hardware implementation. The proposed approach emphasizes deliberate management of design constraints during placement and routing, enabling the consideration of architectural features of programmable computer as well as critical signal paths. The study presents the architecture of programmable computer, identifying and thoroughly analyzing the key characteristics that have the most significant impact on timing parameters, including interconnect structure, the organization of computational blocks, and the distribution of FPGA resources. Based on this detailed analysis, principles for setting design constraints are formulated, ensuring improved timing closure and higher maxi-mum clock frequencies. The experimental section includes the implementation of the proposed approach using existing electronic design automation (EDA) tools, alongside a series of comparative studies employing conventional constraint-setting methods. The comparison is performed at the level of practical hardware implementation, evaluating achieved clock frequencies and result stability. The results obtained demonstrate the advantages of the proposed approach and confirm its applicability for enhancing the efficiency of hardware implementations of FPGA-based programmable computers. This work provides a systematic methodology for constraint management that can be directly applied in FPGA design workflows to optimize both timing performance and overall resource efficiency.

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INTELLIGENT INFORMATION SYSTEMS AND TECHNOLOGIES

K. A. MAIKOV, L. E. TARTYKOV, A. A. BUBNOV. A COMBINED METHOD OF CLASSIFICATION OF VECTOR OBJECTS BASED ON AN ENSEMBLE OF ENCODERS AND CAPSULE MODEL OF TRAITS

Keywords: pattern recognition, vector object, features, capsule network, cascade processing, structural data representation.

This paper considers the problem of pattern recognition using vector object classification methods. A review and comparative analysis of known solutions to practical vector object classification problems using capsule neural networks is provided. A combined method for vector object classification is proposed, combining an ensemble of YOLOv8 detectors for extracting key features of a vector object with a capsule neural network. The use of primary capsules and a dynamic routing mechanism allows for the consideration of spatial dependencies between features. Robustness to input data variability is achieved through cascading expansion of the feature space. The dependence of classification accuracy on the number of features of a vector object and the size of the primary capsule vector is shown. Ranges of model tuning parameters that provide the best balance between accuracy and computational efficiency are identified.

DOI: 10.21667/1995-4565-2026-97-103-112 103

A. A. BULANOV, A. N. PYL'KIN. MODIFIED FUZZY C-MEANS CLUSTERING ALGORITHM IN N-DIMENSIONAL SPACE WITH FEATURE PRIORITIES FOR STUDENT PERFORMANCE ANALYSIS

Keywords: fuzzy clustering, c-means, weighted distance, subject priorities, performance analysis, multidimensional data, adaptive centroids.

A modified fuzzy c-means (FCM) algorithm adapted for n-dimensional space with weighted feature priorities is proposed. The modification introduces an exponent de-

pendent on discipline priority into distance metric, allowing flexible control over the contribution of each subject to the resulting clustering. The method is tested on a sample of 10 000 students across ten disciplines. A comparison is made with classical FCM as well as with previously developed hard k-means methods with priorities and adaptive centroids. The results demonstrate a silhouette index of 0,67, which is comparable to the best hard clustering result (0,68), while additionally providing membership degrees, essential for the analysis of borderline educational trajectories..

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A. N. KOLESENKOV, T. I. KONDRASHOVA. MODULAR ARCHITECTURE AND FORMAL MODELS OF INTELLIGENT CORPORATE GIS DBMS

Keywords: geographic information system, DBMS, PostgreSQL, PostGIS, data audit, spatial index, data integrity, timestamps, trigger functions, corporate GIS.

The aim of the work is to increase the efficiency of spatial data management in corporate geographic in-formation systems by developing and implementing intelligent mechanisms for data auditing and relevance control directly within database management system. The problem addressed is the reduction of dependence of data integrity on application software and the development of autonomous spatial data processing core based on PostgreSQL/PostGIS. The methods used include relational algebra, formal systems theory, spatial indexing techniques, and PL/pgSQL trigger functions. The results include a modular DBMS architecture consisting of six functional blocks: storage, integrity control, auditing, optimization, analytics, and security. A formal model for auditing spatial changes is developed, including mechanisms for ensuring determinism and coverage completeness. A timestamp model is substantiated, and the properties of automatic timestamp updating are investigated. Experimental results show that the use of GiST indexes can accelerate spatial query execution by up to 90 times, while the overhead associated with full geometry auditing does not exceed 14 %. The scalability of the proposed solution is evaluated for datasets containing up to 5 000 spatial objects, corresponding to the requirements of a large municipal GIS. The proposed approach enables the implementation of an intelligent GIS DBMS that provides autonomous spatial data validation, automatic recording of changes, and control of data relevance while maintaining acceptable performance characteristics. The results confirm the practical applicability of the approach proposed for the development of cadastral and municipal information systems.

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T. S. KHODATAEVA, L. E. KARPOV. DEEP LEARNING IN AUTOMATIC OPTICAL INSPECTION OF SEMICONDUCTOR WAFERS: ANALYTICAL REVIEW OF METHODS, 2020-2026

Keywords: automatic optical inspection, semiconductor wafer, wafer map, surface defect, deep learning, convolutional neural network, anomaly detection, review, dataset, quality control.

The paper presents an analytical review of deep learning methods for automatic optical inspection of semiconductor wafers covering 2020 – 2026, complementing the classical review by Abu Ebayyeh and Mousavi that covers the literature up to 2020. The organizing thesis of the review is substantiated: the literature conflates two fundamentally different problems – classification of defect die distribution patterns on wafer maps and detection of micro-scale surface defects at a die level – which differ in data nature, methods, and metrics. For each problem the main development directions are systema-

tized: invariance-embedding and lightweight convolutional architectures, mixed-pattern recognition, and active learning for unknown defect types for wafer maps; the evolution of YOLO-family detectors, segmentation networks, reference-comparison methods, and reference-free anomaly detection for surface defects. Public datasets (WM-811K, MixedWM38, WSDD, MIIC) are analyzed together with approaches to overcoming labeled data scarcity, including diffusion-based and procedural defect synthesis. The influence of optical acquisition scheme (brightfield vs dark-field) on data statistics and architecture choice is discussed, as well as hardware deployment of models (quantization, TensorRT/ONNX, NPU/FPGA). Open problems are identified: domain shift, sensitivity of reference-comparison methods to alignment errors, sub-pixel defects near the diffraction limit, lack of methods for three-dimensional structures (TSV, chiplets), interpretability, and real-time constraints. The transfer of hybrid two-loop paradigm, previously developed by the author for printed circuit board inspection, to semi-conductor wafer inspection is shown to be promising..

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SYSTEM ANALYSIS, MANAGEMENT AND INFORMATION PROCESSING

B. V. KOSTROV, A. A. SOTNIKOV, P. E. SHAMANOV. APPLICATION OF MODAL DECOMPOSITION METHOD OF NON STATIONARY PROCESSES FOR TRAINING INTELLIGENT INFORMATION SYSTEMS

Keywords: non-stationary processes, mode decomposition, process modeling, numerical data processing, intelligent information systems.

The main stages to study the possibility of using mode decomposition method in the general case of non-stationary processes for training neural networks in information systems are described. The aim of the work is to develop a method for modeling a training dataset based on the use of a limited training dataset obtained empirically and the application of non-stationary processes mode decomposition method to provide a sufficient amount of adequate data for training the neural network of information system.

DOI: 10.21667/1995-4565-2026-97-143-152 143

D. G. BELONOZHKO, V. V. PODOLTSEV, D. V. SIDORENKO. DEVELOPMENT OF ALGORITHM TO ASSESS STABLE FUNCTIONING OF UNMANNED AIRCRAFT UNDER EXTERNAL CONDITIONS

Keywords: unmanned aerial vehicle; control channel; navigation channel; sustainable functioning; external influence.

Abstract: the relevance of this study is driven by the growing use of unmanned aerial vehicles (UAVs) in a dense electromagnetic environment and by the presence of targeted threats to their control and navigation channels. The article presents the development of a structured algorithm for comprehensively assessing the level of sustainable functioning of UAVs under a range of external influences. To solve the problem of assessing environmental impacts under uncertainty and imprecise initial data, fuzzy logic is used. The proposed algorithm includes the stages of fuzzification of input parameters, aggregation of rule antecedents, activation and accumulation of consequents using Mamdani implication, and defuzzification to obtain crisp values of the probabilities of information security threat realization and the final probability of sustainable functioning. The scien-

tific novelty of the developed solutions lies in the proposed system of input features, the forms and parameters of membership functions, the fuzzy inference rule base, and the method for forming an integral sustainability indicator based on formalizing the analysis of threats to the security of transmitted information. A structural algorithm implementing the methodology for assessing the sustainable functioning of UAVs has been developed. In the course of the work, the probabilities of information security threat realization in control and navigation channels were determined, and on their basis an integral indicator of the probability of sustainable functioning was calculated. Countermeasures against external influences are proposed, including changes in flight modes and profile. The use of fuzzy logic for real-time decision support systems is substantiated. The application of the developed algorithm enables prompt assessment of the influence of destabilizing factors and the adoption of informed measures to minimize risks. A comparative analysis of various methods (neural networks, gradient boosting, Bayesian networks) for assessing external influences on UAV radio links is presented. A promising direction is the creation of hybrid models combining fuzzy logic with neural network technologies to achieve an optimal balance between speed, interpretability, and computational accuracy.

DOI: 10.21667/1995-4565-2026-97-153-167 153

N. V. ANDREYANOV, M. M. LYASHEVA, M. P. SHLEYMOVICH, D. V. SHCHERBAKOV. TECHNIQUE FOR GENERATING EXTENDED SET OF TRAINING DATA FOR ANALYZING TRAFFIC FLOWS USING DEEP NEURAL NETWORKS

Keywords: modeling of traffic flows, object detection in images, deep learning, augmentation, data set expansion, image transformation, image matting, interactive segmentation.

The problem of expanding datasets for training deep neural networks is considered, through which video images of traffic scenes are analyzed in order to prepare information for building simulation models of urban traffic flows. The analysis of augmentation methods is carried out. The authors show that it is possible to improve the accuracy of vehicle detection in images by applying geometric and color transformations of source data to expand existing training dataset. A technique for forming extended dataset based on the selection of object images on background images is proposed. As a basis for constructing the procedure according to this technique, the use of GrabCut image segmentation algorithms, morphological image processing for forming trimap and matting AlphaMatting images are provided. The results of experiments with a dataset of real images of urban road network are presented, which show the possibility of using the technique to solve the problem of expanding training datasets.

DOI: 10.21667/1995-4565-2026-97-168-182 168

K. A. VASILIEV, A. I. NOVIKOV. ANALYSIS OF MASKED IMAGES RESTORATION RESULTS USING NEURAL NETWORK MODELS

Keywords: blur operator, integral equation, operator kernel, restoration algorithms, regularization algorithm, iterative algorithm, neural network models, restoration estimates.

Image blurring as a method for masking confidential information has gained momentum in recent years. The reliability of this method information concealment remains understudied. The authors of this article demonstrated in previous studies that image blurring using generalized Gaussian kernels provides reliable protection against attempts to restore the masked image using classical methods for solving inverse ill-posed problems.

The potential for restoring a masked image with an unknown kernel of complex shape using known neural network models remains an open question. The aim of this study is to analyze the potential of neural network models with the appropriate profile for restoring images of objects of interest on the underlying surface and typewritten texts masked using blur operators. Two neural network models were examined: Real-ESRGAN (generative) and Swin2SR (transformer). It was found that these neural network models successfully restore images blurred using a simple Gaussian kernel with a relatively short sliding window length. The images blurred using generalized Gaussian kernels with a long non-zero kernel (mask) part could not be correctly restored by neural network models. The obtained result suggests that confidential information can be reliably hidden given the right choice of blur kernel type and parameters.

DOI: 10.21667/1995-4565-2026-97-183-195 183

O. V. MELNIK, M. N. SARAEV. HARMONIC DEVIATION INDEX FOR SPEECH-BASED EMOTIONAL AROUSAL ASSESSMENT

Keywords: Harmonic Deviation Index (HDI), harmonic structure of speech, acoustic descriptor, emotional arousal assessment, speech emotion recognition, fundamental frequency, spectral peaks, median harmonic deviation, emotional speech datasets, stress.

A Harmonic Deviation Index (HDI), an acoustic descriptor characterizing the microinstability of speech harmonic structure is proposed. HDI is computed as the median of relative frequency deviations of spectral peaks from harmonic grid defined by fundamental frequency (F0). The aim of this study is to experimentally verify the sensitivity of HDI to the level of emotional arousal across a wide range of speech corpora. The evaluation was conducted using six publicly available emotional speech datasets (AESDD, ANIEMORE, TESS, RAVDESS, CREMA-D, and ESD), comprising a total of 49 755 recordings in Greek, English, Russian, and Chinese. For each emotional state, median HDI values were calculated, and statistical significance of differences was assessed using Mann – Whitney U test and Cliff's delta. The results show that HDI consistently ranks emotions by psychophysiological arousal level: the highest values were obtained for fear and surprise, whereas the lowest values were observed for neutral speech and sadness. The differences between high- and low-arousal groups were statistically significant across all speech datasets ($p < 0.001$), and the effect size ranged from small to large. The obtained results indicate that HDI can be used as an additional acoustic feature for analyzing emotional arousal and monitoring stress-related states from speech.

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S. I. NOSKOV, S. P. SEREDKIN, V. M. LATSVIEV. CHOOSING A COMPROMISE PLAN IN LINEAR MULTI-OBJECTIVE PROBLEM BY MAXIMIZING WEIGHTED DEVIATIONS FROM THE CENTER OF GRAVITY OF PARETO VERTICES

Keywords: multi-objective linear programming, Pareto set, compromise plan selection, Pareto optimality, decision maker, weighting coefficients, center of gravity of vertices.

A method for choosing a compromise plan in a multi-objective linear problem is proposed, based on maximizing weighted deviations of criteria from the center of gravity of the set of Pareto vertices. Unlike classical linear convolution, the approach uses a geometric benchmark – the arithmetic mean of all efficient vertices – and the weighting coefficients of criteria allow taking into account the subjective preferences of decision maker (DM). A theorem on the Pareto optimality of obtained solution is proved. The

proposed approach makes it possible to purposefully shift the final point along Pareto frontier depending on DM's preferences while preserving Pareto set objective geometry. A numerical experiment illustrates the change in compromise plan with varying criteria weights.

DOI: 10.21667/1995-4565-2026-97-206-213 206

K. E. VORONTSOV. HYBRID ML DECODER WITH ADAPTATION TO CHANGING NOISE PROFILE IN QUANTUM SYSTEMS

Keywords: quantum error correction, quantum computing, error correction, shallow code, machine learning, hybrid ML decoder, online learning, noise drift, hybrid algorithms.

The paper considers the problem of developing a hybrid ML decoder with online adaptation mechanism for error correction in quantum systems with a changing noise profile. The aim is to create and experimentally evaluate the architecture combining a classical stochastic decoder and a neural network block with incremental retraining, capable of maintaining high accuracy under channel parameter drift. To achieve this aim, the following problems were solved: modeling non-stationary and correlated noise, designing modular hybrid architecture, developing online retraining and catastrophic forgetting prevention procedures, and evaluating the effectiveness on synthetic samples. The experiments have shown that the proposed approach provides average decoding accuracy of 0,91 ± 0,03 versus 0,84 ± 0,04 for classical MWPM decoder on a test set (2000 syndromes) during drift modeling, while the adaptive decoder reaches a stable level of accuracy by the 20th epoch. Therefore, hybrid ML decoder improves the robustness of error correction under dynamic noise and is suitable for integration into modern quantum architectures with moderate computational over-head. Hybrid decoder's ability to work with modern quantum processor architectures makes it more useful in real-world quantum devices.

DOI: 10.21667/1995-4565-2026-97-214-222 214

F. I. BASHKIN, S. V. SKVORTSOV. EVALUATION OF AUTONOMOUS NEURAL NETWORK MODELS FOR CONVERSATIONAL SPEECH RECOGNITION UNDER LIMITED COMPUTATIONAL RESOURCES

Keywords: automatic speech recognition (ASR), neural network models, comparative analysis, real-time factor (RTF), recognition accuracy, autonomous systems, local computing, spontaneous speech processing.

The paper addresses the challenge of selecting an effective automatic speech recognition model for fully autonomous operation on local computational resources. The aim is a comparative analysis of the accuracy, performance, and resource efficiency of modern open-source neural network ASR models using spontaneous conversational speech containing slang and non-standard lexicon. Given the constraints of no access to cloud ASR services and the need to ensure data confidentiality, an experimental study of three models differing in architectural principle was conducted. It is shown that the hybrid neural network model provides an optimal balance between processing speed and acceptable accuracy under the given conditions, demonstrating practical suitability for deployment in autonomous speech processing systems. Fundamental difficulties faced by all tested models when dealing with informal lexicon were identified, outlining the key direction for further research.

DOI: 10.21667/1995-4565-2026-97-223-232 223

M. A. POLOZOV, L. A. KOROBOVA, I. S. TOLSTOVA. METHODOLOGY AND SOFTWARE IMPLEMENTATION OF AUTONOMOUS AUDIO TRANSCRIPTION SYSTEM USING NEURAL NETWORK MODELS

Keywords: system construction methodology, neural network models, speech recognition, automatic transcription of audio recordings, diarization, transcription, hybrid architecture, local processing, corporate security.

This article addresses the pressing issue of automatic speech recognition (ASR). With digital transformation and the growth of audio data in corporate environment, the need for effective automatic transcription solutions is significantly increasing. The aim of this study is to develop a methodology for constructing an autonomous automatic audio transcription system and to implement it as a modular software solution based on hybrid client-server architecture, integrating neural network models for automatic speech recognition, speaker diarization, and local large language model (LLM). The research objectives include a comparative analysis of existing transcription systems, substantiation of the methodology for multi-stage audio signal proccesing pipeline, development of algorithms for software solution, and experimental evaluation of system's recognition quality and scalability. The proposed methodology specifies audio-processing sequence, as well as composition and interaction of functional modules. Software implementation of the system uses C# and Python programming languages, integrating the Whisper (transcription), pyannote.audio (diarization), and GPToss (text postprocessing) neural network models. The system implements a multi-stage audio processing pipeline: noise suppression, speaker segmentation, speech recognition, and result formatting. Deployment is performed via Docker/Kubernetes, ensuring scalability and component isolation. Experimental accuracy assessment on a control audio fragment yielded WER values of 7 % and CER values of 3 %, meeting the criteria for high-quality recognition. Key advantages of the solution include complete localization of data processing, open architecture, flexible integration, and scalability. The developed system is an effective software solution for automating audio recording processing in corporate environment, combining the accuracy of modern neural network models with complete localization and independence from network infrastructure. Processing pipeline, server operation, and interactions between their components are described in detail. The results of benchmark tests conducted to evaluate system's accuracy are presented. The main advantages of the developed system are highlighted.

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V. A. MINAEV, A. O. FADDEEV, A. V. KORYACHKO, A. S. KOLOMINA. ESTIMATION PARAMETERS OF «INFORMATION EPIDEMICS» NONLINEAR MODELS

Keywords: information, epidemic model, parameter estimation, global optimization, differential evolution method.

Estimating parameter values of nonlinear models of «information epidemics» based on statistical data from social networks is a global optimization problem with a non-convex gully objective function, which makes it problematic to use standard gradient methods. The aim of the work is to compare common optimization estimation methods for a multiparametric SEIR–like model based on real data. Seven methods were se-lected: DE, DE+polish, multistart L-BFGS-B, CMA-ES, Nelder-Mead, DE+L-BFGS-B, DE+NM. The model is characterized by a quadratic coefficient of information epidemic» spread and a block of content generation in a social network with observable variables – posts, reposts, and comments, from which the full structure of state values and their relation-

ships is restored using the Anylogic simulation platform. The objective function is weighted criterion χ2. The experiment was conducted on the statistics of four information guides (coverage from 2,330 to 2,085 records, observation duration (13 – 29 days). L-BFGS-B multistart showed the best quality (error no more than 1,3 %), CMA-ES showed the best performance (3 – 12 s), and DE+L–BFGS–B hybrid was the optimal compromise for high-sampling data. As a result, a two-stage evaluation strategy is recommended: global DE search followed by local refinement of L-BFGS-B.

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INFORMATION-MEASURING AND CONTROL SYSTEMS

A. I. NOVIKOV, D. S. DOKOV, A. I. EFIMOV, A. S. TARASOV. INFORMATION SYSTEMS FOR MONITORING TECHNOLOGICAL PROCESS PARAMETERS IN METALLURGY

Keywords: information system, laser rangefinder, product profile, surface defect, product range, linear operator, vector mask, polar coordinates.

Modern requirements for production technology in the metallurgical industry involve monitoring the shape and dimensions of the entire product range. This includes monitoring the shape of hot rolled products at the exit of the rolling mill, measuring the dimensions of metal sheets after cutting equipment, monitoring the flatness of sheets before they are fed into the pipe production line, and identifying surface defects in sheet metal during production. The introduction of optoelectronic systems, along with the widespread use of mathematical methods and computers to process information from laser rangefinders, has made it possible to implement non-contact methods of dimensional control in an automated and real-time manner. The integration of optical systems and specialized computer software into a single complex has made it possible to create information systems for monitoring the dimensions of manufactured products and managing technological processes at metallurgical enterprises. The article presents a three-level architecture for building such systems, developed by the NPP «Kogerent» (Ryazan) with the participation of RGRTU employees. At the first level, signal processing (adaptive filtering, calculation of spot coordinates) is performed on an FPGA in real time. The second level on a signal processor provides filtering and profile formation. The third level is specialized software on a computer that solves applied problems on a cloud of points. Three implemented local information systems are considered. The first is a system for monitoring the size and shape (ovality) of hot-rolled rod. The second is a system for detecting and classifying surface defects in sheet metal. The third is an automatic system for controlling the position of the welding machine's head during the welding of the outer seam of large-diameter pipes.

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M. A. PETRUSHIN. ANALYSIS OF PREDICTIVE CONTROL METHODS FOR THE OPERATION OF INTERMITTENT WELLS

Keywords: intermittent well operation, ESP, AR/PSS, model predictive control, MPC, automatic control theory, hybrid systems, intermittent mode stability criterion, edge-of-stability operation, closed-loop control.

The growing share of intermittent well stock equipped with electrical submersible pumps (ESP) calls for a revision of control approaches applied to such objects. Reservoir depletion, elevated gas content and un-stable inflow drive ESP operation close to stall limit and force wells into intermittent operation. The aim of this work is to justify

the choice of a control framework for intermittent ESP wells. The following tasks have been solved: the process was formalized in terms of automatic control theory; the irreducibility of the problem to classical PID control was shown; the choice of predictive control framework has been justified; stability criterion of intermittent regime has been stated in explicit mathematical form; and the resulting justification has been verified by a closed-loop computational experiment. The object is shown to be a hybrid two-phase system with continuous in-cycle dynamics and cycle-to-cycle reassignment of control vector. Neither high-level recommendation systems nor local PID loops account simultaneously for trajectory constraints, cycle-averaged objectives and operation near stability boundary. General statement admits control of both cycle phases; AR/PSS is a particular case for which a verified plant model is available. In closed-loop computational experiment a predictive controller autonomously drove cycle-averaged liquid rate to the prescribed target and maintained it within ± 5 % while respecting intake-pressure constraint.

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M.S. AFANASIEV, T.V. BUDKINA, L.A. KARAVDIN, A.M. MAKSIMENKO, A. YU. MOKHOV, YE. S. YANOV. INFORMATION AND MEASUREMENT EQUIPMENT MONITORING SYSTEM IN STAMPING PROCESSES CONTROL

Keywords: information and measurement system, indirect control, product quality, stamping, neural network model, vibration diagnostics, information asymmetry, critical information infrastructure, predictive analytics, decision theory, game theory, matrix game, Bayesian approach, economic efficiency, maintenance.

The relevance of the study is due to insufficient reliability of primary information about technological processes of production in the conditions of traditional human-oriented control. This problem creates an in-formation asymmetry between management and staff, and also increases uncertainty during the operation of forging and pressing equipment (FPE) due to the dynamic changes in its load and technical condition. The aim of the work is to develop the architecture of indirect control information and measurement system with a decision support function based on game theory apparatus to improve the objectivity of quality management and the efficiency of equipment operation. The objectives of the work include: creating a system based on piezo accelerometers, current sensors and neural network processing; integrating the data obtained with a game model for choosing service strategies; clarifying a priori probability distributions using Bayesian approach. The scientific and practical results obtained are as follows: the proposed architecture makes it possible to move from selective to continuous monitoring, from subjective assessments to quantitative criteria (threshold values of vibration acceleration and current signals for classifying states are given in the work), from after-the-fact analysis to monitoring the condition of equipment in real time. A statistical game model has been developed where an enterprise chooses maintenance strategies and operating modes, and environment is represented by loading and wear conditions. Calculations of economic efficiency are performed using the example of hydraulic presses fleet; experimental vibroacoustic portraits for standard and defective conditions are presented. Thus, based on the conducted research, the authors can conclude that the use of game models with objective system data increases the expected profit by 26 % compared to traditional methods, provides documented decision support, reduces the risks of sudden failures and optimizes maintenance costs.

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A. M. ABRAMOV. METROLOGICAL TESTING OF ABSOLUTE ENCODERS BASED ON SLIDING HISTOGRAM METHOD

Keywords: sliding histogram method, precision technique, illuminance sensor, built-in ADC, quantization interval, over-all histogram, differential nonlinearity (DNL), integral nonlinearity (INL), transfer function.

The problem of metrological testing of illuminance sensors with built-in analog-to-digital converter (ISADC) is considered. The aim of this work is to adapt the sliding histogram method for ISADC testing, which makes it possible to reduce the requirements for the accuracy of light exposure measure through the use of precision techniques. A structural diagram of a device implementing metrological testing of ISADC based on a sliding histogram method is proposed. An important feature of a new method is the use of two light sources to generate stable and controlled resultant illuminance on the sensing element of the sensor. An algorithm for acquiring local histograms while shifting generated illuminance across entire operating range of the sensor is described. The author shows how differential (DNL) and integral (INL) nonlinearities of the sensor are calculated from the constructed overall histogram. The nonlinearity error in a new method occurs only in case of combined nonlinearity of generated illuminance and error in its constant component level shift.

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A. M. ABRAMOV. METROLOGICAL TESTING OF ILLUMINANCE DIGITAL SENSORS WITH BUILT-IN ADC BASED ON SLIDING HISTOGRAM METHOD

Keywords: sliding histogram method, precision technique, absolute encoder, reduction, quantization interval, overall histogram, differential nonlinearity, integral nonlinearity, transfer function.

The problem of metrological testing of absolute encoders (AE) is considered. The aim of this work is to adapt a sliding histogram method for AE testing, which makes it possible to reduce the requirements for the accuracy of mechanical angular input measure through the use of precision techniques. A structural diagram of a device implementing AE metrological testing based on a sliding histogram method is proposed. An important feature of a new method is the formation of resultant angular action on AE input shaft by summing independently generated variable and constant angular components, the step of which is mechanically reduced. An algorithm for acquiring local histograms while shifting constant angular component with a step close to the expected angular step of AE up to a full revolution of its input shaft is described. The author shows how differential (DNL) and integral (INL) nonlinearities of AE are calculated from the constructed overall histogram. Nonlinearity error in a new method occurs only in case of combined nonlinearity of variable angular component and an error in the step of constant angular component shift.

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M. S. GALUSHKA, V. YU. VISHNEVETSKIY. SELECTIVE ADAPTIVE LMS FILTERING ALGORITHM OF OCULOGRAPHIC ARTIFACTS FOR PORTABLE NEUROFEEDBACK SYSTEMS

Keywords: electroencephalography, adaptive filtering, LMS, neurofeedback, blink artifacts, mathematical modeling, bio-feedback.

The effectiveness of neurofeedback systems (EEG biofeedback) critically depends on the quality of real-time signal cleaning from oculographic artifacts. For portable single-

channel devices, classical filtering methods often prove ineffective or introduce significant distortions into a useful signal. This paper proposes and mathematically justifies a selective hybrid algorithm based on the Least Mean Squares (LMS) filter. A key feature of the method is the use of an auxiliary frontal channel for gating the filtering process and optimizing the convergence step exclusively on artifactual data segments. For an objective evaluation of the approach proposed, numerical modeling was performed on semi-synthetic data with known reference signal. The results showed that the developed algorithm provides artifact suppression at the level of 7,77 dB, while maintaining the power of diagnostically significant biorhythms (alpha, SMR rhythms) with an error of no more than 0,1 – 9,1 %. The proposed solution minimizes root-mean-square error of signal reconstruction and does not introduce distortions into EEG activity during periods of no interference, which makes it optimal for precision mobile rehabilitation systems.

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PHYSICAL ELECTRONICS AND NANOELECTRONICS

N. B. RYBIN, N. V. RYBINA, A. I. IVANOV, V. V. TREGULOV, K. O. AIYYZHY, E. V. BARMINA. OPTICAL PROPERTIES OF SILVER NANOPARTICLES ARRAYS FORMED ON SMOOTH SILICON SUBSTRATES

Keywords: monocrystalline silicon, silver nanoparticles, electroless deposition, localized plasmon resonance, scanning electron microscopy, diffuse reflectance spectra.

The paper investigates the optical properties of silver nanoparticle arrays formed on smooth single-crystal silicon substrates of KEF 4.5 type with (100) orientation by electroless deposition. The surface morphology and diffuse reflectance spectra were studied. The authors show that the shape of reflectance spectra in short-wavelength region is due to localized plasmon resonance, while in long-wavelength region, it is due to particle size and their distribution on surface. It was found that varying the duration of silver particle deposition leads to a change in their size and localized plasmon resonance wavelength shift. The effect of silver particles shape on localized plasmon resonance wavelength shift is insignificant.

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B. A. KOZLOV, D. S. MAKHANKO. CATALYTIC PROPERTIES OF CORONA DISCHARGE IN CO2-LASER MIXTURES AT ATMOSPHERIC PRESSURE

Keywords: corona discharge, gas discharge catalyst, dissociation, carbon dioxide regeneration, resource.

The possibility of carbon dioxide regeneration from the products of its dissociation in CO_2 laser mixtures of atmospheric pressure under the influence of corona discharge plasma is demonstrated. Quantitative information has been obtained on the temporal behavior of carbon monoxide and molecular oxygen concentrations from the magnitude of the corona discharge current and the polarity of the voltage at the corona electrode. It has been established that a negative corona discharge provides the efficiency of carbon dioxide reduction than a positive corona discharge.

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M. S. TYSHCHENKO, G. P. GOLOLOBOV, S. A. KRUGLOV, E. V. SLIVKIN. PHYSICAL AND TECHNOLOGICAL FUNDAMENTALS OF INCREASING SERVICE LIFE OF MEMS SWITCHES

Keywords: microelectromechanical switch, MEMS, electrochemical deposition, contact resistance, electroplating, Ni-W.

The aim of this work is to analyze technological solutions for increasing the service life of microelectro-mechanical switches, as well as methods for improving their performance. The possibilities of reducing contact resistance of devices and stabilizing it by controlling surface roughness of contact pads are discussed. The materials used for contact coatings are presented in detail, and the most promising options based on W-containing alloys are proposed. Conditions and modes for their production are presented. Various design methods for increasing contact force and magnetic sensitivity of devices are considered. The prospects for various design variants of MEMS switches and materials used in contact pads are analyzed.

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A. A. SHVACHKO. MODERN TRENDS IN THE DEVELOPMENT OF MAGNETIC FOCUSING SYSTEMS FOR MICROWAVE DEVICES

Keywords: magnetic focusing system, permanent magnet, onboard equipment, terahertz frequency range.

This article presents an analytical review of current trends in the development of magnetic focusing systems (MFS) used in modern microwave devices. The aim of the study is to examine key factors determining the evolution of these devices, including ongoing miniaturization of devices, the transition to terahertz (THz) frequency range, and the need to optimize weight and size characteristics for use in onboard space and aviation equipment. The study included a comparative analysis of various focusing system configurations, including homogeneous, periodic (PPM/PCM), and hybrid magnetic systems, as well as promising solutions for multibeam and ribbon electron beams. The research methodology is based on a systematization of modern technological approaches to the design of microwave devices and critical assessment of their performance at high frequencies. The results of the study demonstrate that modern MFSs are evolving toward deep integration with electron gun and slow-wave structure, which is becoming possible through the implementation of microelectronic technologies (MEMS, precision ion etching). The authors demonstrate that achieving the required parameters in THz range requires new high-coercivity materials, such as neodymium-based alloys (NdFeB). The authors conclude that further development of the industry will be driven by the synergy of vacuum and semiconductor technologies, enabling the creation of high-power and compact THz radiation sources for sixth-generation (6G) communication systems and advanced radar systems.

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