

## CONTENTS AND ABSTRACTS

### RADIO ENGINEERING AND RADAR

#### **A. S. Sychev, I. S. Kholopov.** IMAGE FUSION BY THE METHOD OF PRINCIPAL COMPONENT ANALYSIS WITH ADAPTATION TO NOISE POWER

Key words: multispectral vision system, image fusion, principal component analysis, signal to noise ratio, modified gray level variance, image quality measures.

We consider the problem of image fusion by multispectral vision system in which quality criterion is peak signal-to-noise ratio. The aim of the work is to develop a fusion algorithm that allows creating an image that is comfortable for a subjective observer, even if the image in one of the channels of multispectral vision system contains powerful high-frequency noise component. Experimental results show that the algorithm developed provides the gain in a peak signal-to-noise ratio by 3.4 and 4.6 times compared with the known fusion methods based on principal component analysis and arithmetic mean calculation respectively.

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#### **I. S. Kholopov, I. A. Lyutkov.** COMPARATIVE ANALYSIS OF TWO METHODS OF NONLINEAR OPTIMIZATION IN THE PROBLEM OF CALIBRATING THREE-AXIAL MEMS ACCELEROMETER

Key words: MEMS accelerometer calibration, Gauss – Newton method, Levenbergh – Marquardt method.

The aim of the work is a comparative analysis of Gauss – Newton and Levenberg – Marquardt optimization algorithms in the calibration problem of triaxial micro electromechanical accelerometer. A mathematical description of these algorithms is given; their advantages and disadvantages in solving the problem of optimizing the parameters of a simplified mathematical model of triaxial micro electromechanical accelerometer by the criterion of minimum error squared are noted. It is shown that with identical parameters of the model, Levenberg – Marquardt algorithm requires an average of 30 % more iterations to complete than Gauss – Newton algorithm, however, when applied, the error in estimating the elements of the vector of calibration parameters decreases by 20-30 %.

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#### **E. P. Vasilyev.** SIMULATION OF MICROWAVE DIVIDER-COMBINER POWER AMPLIFIER SUBMODULES

Key word: directional coupler, electrodynamics and circuit modeling, phase-shifting circuit with distributed and lumped parameters, data from a machine experiment, divider-combiner power, submodules of power amplifiers of L, S and X-band.

The problem of electrodynamics and circuitry modeling of a three-stage three-decibel microstrip directional coupler with phase-shifting circuit between sections is considered. The aim is to research the original design solutions of three-stage directional couplers with a phase-shifting circuit between quarter-wave sections. The possibility of eliminating jumpers between sections due to the use of phase-shifting circuit with distributed and lumped parameters to increase the manufacturability and stability of the parameters of directional couplers with strong coupling is justified. The correctness of the simulation results obtained is confirmed by a comparative analysis of machine experiment data and the introduction of directional couplers into the submodules of power amplifiers of L, S and X-ranges.

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#### **D. V. Bilevich, A. A. Popov, I. M. Dobush, A. E. Goryainov, Y. A. Novichkova.** STUDY OF MICROWAVE TRANSISTOR MEASUREMENT SMOOTHING ALGORITHMS FOR SMALL-SIGNAL NOISE MODELING

Key words: small-signal model of transistor, noise model of transistor, noise figure, smoothing technique, low noise amplifier.

The problem of preliminary processing of measurement results of a microwave transistor in terms of building a small-signal noise model with subsequent application of these models in de-

sign process is studied. The aim is to verify the applicability of methods for removing noise from measured data in the process of building small-signal noise models of a transistor. A preliminary check of four smoothing methods on artificially noisy model data was carried out. It was found that the error in removing noise by the Savitsky-Golay method on artificially noisy data does not exceed 2.5 %. The applicability of the method was experimentally verified by constructing a small-signal noise model of microwave transistor. Using the constructed model, the design and the subsequent manufacture of test monolithic integrated circuit (MIC) of a two-stage low noise amplifier was carried out. The deviation of measurement results from simulation results was less than 10 % for both gain and noise figures. This suggests that it is possible to apply smoothing procedure to measurements of noise figure by the Savitsky-Golay method in the process of building a small-signal noise model.

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## MATHEMATIC AND SOFTWARE COMPUTER SYSTEMS AND COMPUTER NETWORKS

**Yu. L. Leokhin, T. D. Fatkhulin.** ESTIMATION OF THE POSSIBILITY TO PROVIDE GUARANTEED DATA RATE FOR A CLIENT IN SOFTWARE-DEFINED OPTICAL NETWORK

Key words: multiservice telecommunication network, service, software-defined optical network, guaranteed data rate, share of blocking calls, channel resource, flow of calls, mathematical model, method.

The problem of estimating the possibility of providing a guaranteed data rate (Bandwidth on Demand service) to a client in Software-Defined Optical Networks (SDON) is considered. The aim is to find the main indicators of the quality of service of call flows in the SDON. The relevance of the work is due to the growing interest in «cloud» online-services, requiring guaranteed bandwidth for their work on demand. It is proposed to estimate the quality of service using the share of blocking calls and the math model of a multiservice network using the sifted load method. A system of implicit equations is solved to find the share of blocking calls. The required values are experimentally determined for the generalized network structure. The results make it possible to determine with high accuracy the possibility of providing the Bandwidth on Demand service.

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**A. P. Shibanov, A. D. Nguyen, A. M. Pham.** STOCHASTIC NETWORKS USAGE WHEN PLANNING PROFIT TAKING INTO ACCOUNT POSSIBLE LOSSES

Key words: GERT-networks, random variable, inversion formula, probability density, characteristic function, functional dependence of distributions, inverse function, normal distribution, planned profit, loss of profit.

The aim of the work is to use GERT-networks to solve the problems of calculating the real profit of the enterprise taking into account negative factors. For each operation of GERT-network, the planned optimal profit value is determined. The profit of individual operations is summarized. For each operation, a random value of profit losses is determined by the imperfection of simulated process. Losses are determined either by a functional relationship between random variables or independently on the basis of statistical data. The planned profit is specified taking into account its losses using positive and negative random values of GERT-network. Elementary basic transformations in GERT-network with positive and negative random variables are analyzed. The possibility of converting GERT-network with positive and negative random variables to a single equivalent arc obtaining probability distribution density of its output value is proved.

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## INTELLIGENT INFORMATION SYSTEMS AND TECHNOLOGIES

**I. Yu. Kashirin.** HIERARCHIC NUMBERS FOR THE DESIGN OF ICF-TAXONOMIES ARTIFICIAL INTELLIGENCE

Key words: knowledge models, artificial intelligence, ICF ontology, ontological taxonomies, hierarchical numbers, instrumental software, intelligent problem solvers, Semantic Web tech-

nology, information retrieval in global networks, generic and causal relationships, dichotomy, polymorphic representation of knowledge.

The most important task of designing taxonomies for knowledge models of artificial intelligence is considered. As a basic taxonomy relation, ICF adjacency relation is proposed to be used. Such an approach makes it possible to efficiently design general and applied ontologies for solving problems of artificial intelligence. The article introduces original mathematical apparatus of hierarchical numbers, which makes it possible to analyze general ICF ontologies by calculating the main characteristics of taxonomic hierarchies. Such characteristics include, for example, generality measure for two or more concepts or the complexity of structural path in a taxonomic hierarchy between two concepts. As an example, confirming the possibility of the effective use of ICF taxonomies in solving real problems of artificial intelligence, general taxonomy with the name «spatial situation» is proposed. It shows the possibility of using heuristic programming tasks in intelligent solvers and in intelligent systems to search information resources in global networks, for example, in Semantic Web technology. In the experimental part, to test the capabilities of information retrieval in global networks based on Semantic Web technology using ICF taxonomy, ICF PUTE v.2.02 (ICF polymorphic unification tools environment) software system is considered. ICF PUTE system implements the search in global networks using the means of structuring and unification to work with the content of global networks. The purpose of this subsystem is to verify the operation of the means to structure ICF ontologies for solving applied search problems. The aim of the work is to analyze design features of general and applied ICF ontologies using hierarchical number apparatus for the effective solution of urgent problems of artificial intelligence.

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**L. A. Demidova, M. A. Stepanov.** APPROACH TO CHOOSING THE FUZZY REGRESSION MODEL IN THE PROBLEM OF ANALYZING THE INDICATORS OF SOCIO-ECONOMIC SPHERE, REPRESENTED BY THE TIME SERIES

Key words: time series, model, fuzzy regression equation, triangular fuzzy number, genetic algorithm, socio-economic sphere.

The problem of choosing fuzzy regression model in the problem of analyzing the indicators of socio-economic sphere represented by time series has been considered. The aim of the work is to develop the approach to choose fuzzy regression model by implementing a genetic algorithm which simultaneously searches the type of fuzzy regression equation and the values of its parameters. The equations of linear, quadratic, exponential, and logarithmic fuzzy regressions with asymmetric parameters encoded using triangular fuzzy numbers have been considered. The examples of constructing fuzzy regression models using the proposed approach in the problem of analyzing the indicators of socio-economic sphere presented by time series confirming its effectiveness have been given.

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**O. D. Kazakov, N. Yu. Azarenko.** COMBINING MACHINE LEARNING METHODS AND SIMULATION MODELING OF SOCIO-ECONOMIC PROCESSES IN DECISION SUPPORT SYSTEMS

Key words: machine learning; simulation modeling; decision support systems; human potential model of the region.

Three modes of joint application of machine learning and simulation methods in decision support systems are studied. The purpose of this work is to apply these methods jointly to improve the efficiency of generating proposals and conducting appropriate analysis in decision support systems for managing socio-economic processes and systems on the example of a human potential research in the Bryansk region.

In the context of approbation of design solutions, this work aims to develop a predicative model of the human potential of the Bryansk region. To generate synthetic data necessary for training the primary neural network of long-term short-term memory, the authors have developed a simulation model of the region's human potential. The main approaches to modeling are defined as system dynamics and agent-oriented approach. On the basis of transfer training, the pre-trained model is transferred to the solution of forecasting tasks on real data.

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## SYSTEM ANALYSIS, MANAGEMENT AND INFORMATION PROCESSING

**A. E. Moskvitin. INTEGRATION OF VIDEO INFORMATION FROM A VARIETY OF SPACE- BASED EARTH OBSERVATIONS**

Key words: integration of heterogeneous images, multi-zone thermal and radar images, increasing clarity and decipherability of images.

Approaches to combine heterogeneous video information from various Earth space sensing systems are considered. The aim of this task is to obtain a new image that improves clarity and decipherability of the objects in the scene being observed. The analysis of domestic and foreign publications on this topic is presented. A number of approaches to solve this problem are described.

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## MATHEMATICAL MODELING TECHNICAL SYSTEM

**K. A. Maikov, A. N. Pylkin, S. N. Kuzmenko, A. A. Teplov. ALGEBRAIC FEATURES OF FRACTAL STRUCTURE CALCULATION ALGORITHMS**

Key words: geometric fractals, stochastic fractals, algorithms to construct fractals, algebra of fractal operators.

The analysis of the methods to construct known geometric fractals allowed revealing algebraic features of fractal algorithms composition, namely fractal operators  $f_i$ , which are the basic operations to construct fractals of a certain type. The result of using operators for geometric fractals is the structure with fractures of triangular, square, trapezoidal, etc. forms. Multiplication and addition operations are introduced for the operators, as well as the concept of unit, zero and inverse operator which allows us to define periodic and quasi-periodic fractal structures. In the product with an infinitely large number of cofactors-basis operators it is possible to obtain ultimate generalization of the concept of fractal as a structure without self-similarity, but with naturally decreasing scale. Fractal operators  $f_i$  have complex switching properties. Giving stochastic character to basic operators  $f_i$  allows calculating stochastic fractals and analyzing regularities of their structure. For periodic fractals, as well as the union of fractals, average or generalized dimension is introduced. An algorithm to form periodic and stochastic fractal structures is proposed, a distinctive feature of which is the implementation of probabilistic choice of basic geometric primitive on current iterative cycle. Software implementation of the algorithm proposed confirmed the validity of algebraic approach in study and modeling of fractals with complex structure.

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**B. A. Alpatov, P. V. Babayan, I. E. Evteev. MODELING THE OPERATION OF TECHNICAL VISION SYSTEM WITH STRUCTURED LIGHT**

Key words: simulation, technical vision system, structured light, DirectX, depths map, Z-buffer.

The problem of developing a method for modeling the operation of technical vision system with structured light is considered. The aim of this work is to develop software that allows you to simulate the operation of technical vision system with structured light in real time. Simulation of the scene was performed in a flight simulator, which allowed us to get plausible behavior of aircraft. Using DirectX capabilities, the simulator extracts information about the distance to each pixel of an image (depths map) and the scene image itself. Range map allows you to calculate the intersection of structured light beams and scene objects. To optimize the calculation of intersection points, Bresenham's algorithm is used. The found points are superimposed on the scene image obtained from simulation environment. It is shown that this method allows achieving the simulation of system operation in real time.

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**K. V. Bukhensky, A. N. Konyukhov, A. B. Dubois, A. S. Safoshkin. FUZZINESS TRANSFORMATIONS ON LINEAR OPERATIONS WITH LR-TYPE FUZZY NUMBERS**

Key words: fuzzy set, LR-type fuzzy number, membership function, shape function, index of math fuzziness, spread vagueness, Zadeh's extension principle, alpha-cut of a fuzzy set.

The aim of the work is to investigate fuzziness transformations on functional mapping fuzzy sets (FS) and on linear operations (FSs addition and multiplication FS by real number). FS are represented by LR-type fuzzy numbers (FN) used as linguistic variable term sets in fuzzy inference systems. The notions of spread vagueness and math fuzziness were differentiated. As a measure of FS's math fuzziness the Yager's index of fuzziness with linear metric was chosen. Math fuzziness index was shown to be invariant with respect to linear functional transformations of FSs as well as to addition of LR-type FNs with similar shape functions. The formula for math fuzziness index for the sum of LR-type FNs with different arbitrary shape functions is derived. In order to prove theoretical results numerical experiments were accomplished.

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**M. V. Zharov. OPTIMIZATION MODELLING FOR ORGANIZATION OF PRODUCTION OF MECHANICAL ENGINEERING WORKSHOPS IN THE ANYLOGIC SOFTWARE ENVIRONMENT**

**Key words:** simulation modeling, production model, material flow, motion simulation of semi-finished products, equipment load factor, production logistics, production environment, instrumentation, instrumentation workshops, optimization of production processes.

In this paper, we study the possibilities of applying the technology of production environment simulation using AnyLogic software package at the enterprises of instrument-making and machine-building industries. The possibilities of using simulation of technological processes of instrumentation to solve production problems are investigated. An example of solving optimization problem to identify organizational problems and improve the work of machining workshop is given. The aim of the article is determining the prospects of using simulation in AnyLogic environment during optimization processes when determining the optimal amount of production equipment, determining the actual load of equipment, determining the efficiency of using workshop area and solving production logistics problems at modern engineering enterprises.

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**A. O. Faddeev, S. A. Pavlova. INTEGRAL RISK ASSESSMENT MODEL OF GEODYNAMIC ORIGIN EMERGENCY SITUATIONS**

**Key words:** Mathematical model, geodynamic stability, seismic activity, aftershock, foreshock, risk assessment; shear deformations; displacement vector.

The aim of the work is construction and analysis of a mathematical model for assessing the risk of emergencies of geodynamic origin for regions within which the main initiating seismic events take place, and then successive aftershocks at various depths were recorded within the same territories.

When constructing a mathematical model, methods of continuum mechanics and methods of the theory of differential equations were applied.

The mathematical model presented allows calculating displacements in geological environment based on the sequence of occurring seismic events. The model can be used both in real time and in a prognostic sense.

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**A. N. Kabanov, D. N. Folomkin. IMPROVING THE EFFICIENCY OF MULTIVARIATE TIME SERIES ANALYSIS**

**Key words:** multidimensional representation, multidimensional time series, white noise, color noise, clustering, Prim's algorithm, recurrence estimates, moving interval, approximation, decomposition coefficients, time scale factor.

The problem to increase the efficiency of multidimensional time series analysis is considered. The aim of the work is to find solutions to increase the efficiency of multidimensional time series analysis. Several approaches are proposed to optimize the analysis, namely: the use of an operational algorithm for determining the optimal temporal scale factor of spectral decomposition under color noise conditions, clustering of multidimensional time series based on Prim's algorithm, and obtaining recurrent estimates of the approximation of multidimensional time series on a moving interval.

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## PHYSICAL ELECTRONICS AND NANOELECTRONICS

**B. A. Kozlov, Mai The Nguyen.** EFFECTIVE AUTO-EMISSION COATINGS OF CATHODES OF SMALL-SIZED TEA-CO<sub>2</sub> LASERS BASED ON NANOSTRUCTURED CARBON MATERIALS

Key words: nanostructured forms of carbon, field electron emission, volume discharge current, current density, pump energy, CO<sub>2</sub> laser mixture.

The effect of nanostructured carbon coatings on current density and pump energy in small-sized sealed-off TEA-CO<sub>2</sub> lasers is studied. It has been established that the deposition of thin layers of carbon soot containing carbon in various nanostructured forms contributes to the increase in current density of pumped volume discharge by 1,5-2,2 times and pump energy density by 2-2,4 times in CO<sub>2</sub> laser mixtures at atmospheric pressure. The aim of this work was to experimentally study field-specific characteristics of cathodes coated with carbon soot and to determine the relationship between volume density of current and pump energy in discharge gaps formed by metal electrodes and the same electrodes coated with a layer of carbon soot.

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**E. A. Grechushnikov, D. V. Prokofiev, E. V. Salyuk, A. V. Nabatchikov.** TEST LEAD STORAGE BATTERIES IN THE CONDITIONS OF CONTROL AND TEST STATIONS

Key words: battery, control and test station, self-discharge, density, electrolyte, EMF, chemical composition, charge.

This work is devoted to the experimental study of performance characteristics shown by lead-acid starter batteries. The aim of the work was to study time patterns of self-discharge processes of batteries depending on modes, terms and conditions of operation, in particular, changes in their open circuit voltage, chemical composition and electrolyte density. Operating conditions of different climatic zones, which vary widely, were simulated in special control and test stations. It is shown that the increase in the content of impurities in electrolyte solution and, to a greater extent, its increased temperature leads to the increase in self-discharge. Multi-day self-discharge time constant allows providing self-discharge compensation at the level of decline in units of ampere hours.

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**S. S. Volkov, M. E. Ilyin, V. D. Rogachev, A. V. Nabatchikov.** SIMULATION OF CHANGES IN ELECTRICAL CHARACTERISTICS OF LEAD-ACID BATTERY

Key words: battery, lead, charge capacity, self-discharge, diffusion, simulation, migration, grids, antimony, active mass.

The paper is devoted to theoretical modeling of physical and chemical processes in accumulators. The aim of the work was to study physical and chemical causes and regularities of self-discharge of lead-acid battery, build a mathematical model and an algorithm for creating self-discharge compensation devices. The analysis of processes that change electrical characteristics of lead-acid batteries is carried out. The process of diffusion of antimony atoms from the rods of current-carrying grids of electrode plates and antimony scattering over battery volume, in particular, segregation of antimony on the surface of active mass of negative electrode in the form of a two-dimensional film and positive electrode in the form of three-dimensional formations, is considered. On the basis of known laws, an analytical model for changing the EMF of lead battery has been developed. Comparison of analytical models of antimony transition processes from grids on the surface of active electrode masses showed satisfactory correlation by time changes between them.

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**A. E. Chizhikov, M. I. Galitsyn.** INVESTIGATION OF HEATING EFFECT ON EFFICIENCY AND LIGHT OUTPUT OF POWERFUL SINGLE CRYSTAL LED SOURCES OF WHITE LIGHT WITH PHOTOLUMINOPHOR

Key words: white light source, blue LED, single crystal, GaN, quantum wells, relative efficiency, theoretical CVC of LED, light output.

The aim of this work is to identify the main reasons for the decrease in efficiency of «blue» GaN/InGaN chips with quantum wells and light output of powerful single crystal SWL based on them - TDS-P003L4U10 (3 W, 220 Lm), Cree XM-L2 (10 W, 1040 Lm), identification of best operating conditions and development of recommendations to improve SWL quality. The results of measuring relative brightness of chips blue radiation and total brightness of SWL white color formed by the radiation of chip and photoluminophore are presented. Calculation of change in diode voltage was carried out taking into account the dependence of free carriers concentration, band gap, and the density of states on temperature. It was revealed that in TDS-P003L4U10 the CVC deviation and decrease in efficiency are caused by increasing (0,6-0,86) Om resistance of contact wires connecting the crystal with high-current output with increasing current (temperature) and in Cree XM-L2 – decreasing with increasing series resistance (0,46-0,24) Om of GaN layers (p, n) and substrate. The calculated efficiency value at operating currents for TDS-P003L4U10 (0,7 A) is 0,82, for Cree XM-L2 at the current of 0,7 A – 0,91, and at 3 A – 0,79. The decrease in relative light output is also associated with CVC deviation.

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#### **A. N. Shesterkin. DETERMINING SAMPLE SIZE TO RESEARCH IGNITION DELAY TIME**

Key words: gas discharge indicator, delay time of discharge occurrence, exponential distribution, estimation of average delay time, sample size, errors of statistical estimates, histogram, confidence interval, statistical modeling.

Temporal processes in gas-discharge matrix indicators, both under autonomous excitation of elements and under ionization conditions, are quite accurately described by exponential distribution. The aim of this work is to analyze methods for calculating the number of elements in a sample that provide determination of ignition delay times statistics. Methods for calculating a sample size for estimating mathematical expectation of delay time, the number of measurements and the quantity of histogram intervals, which ensure that experimental distribution agrees with exponential parametric and nonparametric methods, and that the histogram is presented with necessary accuracy, are considered. Confidence intervals of mathematical expectation estimates, displacements and probabilities of random values falling into the histogram intervals are defined. Recommendations to determine sample size needed to build a histogram and to estimate mathematical expectation are formulated. The accuracy of the results was confirmed by statistical modeling.

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#### **S. V. Ryzhov, V. V. Andreev, D. M. Akhmelkin, M. V. Romanov. CONVERSION OF MOS TRANSISTOR MODEL FOR SPICE SIMULATORS**

Key words: EKV model, semiconductor device modeling, analog IC designing, MOS transistor, CAD Cadence Virtuoso.

This paper provides a brief description of the algorithm for extracting and selecting parameters of the EKV model of the MOS transistor. The aim of the article is develop program to convert the BSIM model to the EKV model based on the original methodology for extracting parameters of a compact model developed at the Ecole polytechnique federale de Lausanne. In this work SPICE model for standards 0.35 microns technology from XFAB was converted. Converted EKV model well correlated with the simulation data of the BSIM model. Based on the EKV compact model, parameters were extracted for the simplified EKV model for manual calculations. In the future, the resulting models can be used in the design of low-voltage analog circuits and RF circuits.

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