ABSTRACT AND REFERENCES

MATHEMATICS AND CYBERNETICS – APPLIED ASPECTS

MATHEMATICAL MODELING OF SOIL CONTAMINATION AS A RESULT OF TECHNOLOGICAL PROCESSES (p. 4-9)

Andrij Olijnyk, Alisa Moroz

We have analyzed contaminated areas of anthropogenic origin, particularly surface and underground water as well as soil. We have considered the state and nature of processes happening within the Dombrov mine (mining potash) and other industrial areas of Ukraine that are vulnerable to technogenic impact. The suggested mathematical models of diffusion processes are based on the use of two- and three-dimensional diffusion equations with a wide range of boundary and initial conditions. It is determined that exact solutions inhibit studying the peculiarities of their behavior depending on the type of boundary conditions, therefore we suggest using numerical solutions. The presented difference schemes of the method of variable directions for numerical realization of two-dimentional models in different frames account for environmental heterogeneity of matter distribution. The schemes allow to measure concentration of substances in real objects through building functions that model various boundary conditions. We have devised a program complex for their implementation and presented the test findings as well as their analysis. To model processes whose parameters depend on three spatial coordinates, we have suggested numerical schemes for implementing three-dimensional models that are absolutely stable and have the second order of accuracy at all spatial coordinates. The study is completed with specification of the directions for further research.

Keywords: environmental state, anthropogenic factors of impact, mathematical model, diffusion equation.

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COMPARATIVE ANALYSIS OF SOME COMPUTATIONAL SCHEMES FOR OBTAINING A COMPROMISE SOLUTION (p. 10-18)

Olga Sanginova

The comparative analysis of the effectiveness of the five most common computational schemes for the compromise solutions in multi-objective optimization tasks involving the convolution of criteria is conducted. The study is performed for a number of innovative technologies of formation of multifunctional biopolymer materials.

The criterion that allows to evaluate the effectiveness of different types of package is formulated. In accordance with the proposed criteria, the most effective for the regarded group of tasks is the maximin convolution. The use of the additive and multiplicative convolutions is restricted by the convex programming problems; the convolution using the Harrington's desirability function requires testing the hypothesis of normal distribution, and the method of ideal point involves only the formulation of the necessary conditions for the existence of an extremum, so these solutions do not always meet the technological constraints.

The adaptation of computational schemes for solving the constrained optimization tasks and their software implementation using object-oriented programming language Visual Basic for Application is created.

The obtained results can be used to improve existing and develop new technologies forming biopolymer materials.

Keywords: compromise area, optimization task, physical and chemical processes, polyfunctional biopolymer materials.

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APPLICATION OF INTERVAL MATHEMATICAL MODELS OF OPTIMIZATION PLACEMENT PROBLEMS OF GEOMETRIC OBJECTS (p. 18-26)

Lyudmila Yevseeva

At present, the methods of mathematical modeling of real objects and processes play an important role in developing systems, aimed at processing geometric information. Such systems are based on mathematical models of real world objects, optimization methods and theory of building intelligent systems. The research is focused on the applied aspects of interval mathematical modeling in a geometric design.

The classification of implementations of the interval mathematical model of the basic interval optimization placement problem, many implementations of which covers a broad class of scientific and applied placement problems, according to the type of classification of mathematical programming problems was performed.

Various types of interval mappings of interval mathematical models in Euclidean space for the transition from the optimization problem in interval space to an equivalent optimization problem in Euclidean space were constructed.

The method for solving the interval optimization problem in $\mathbf{I}^n_s\mathbf{R}$ as the two-criteria optimization problem in Euclidean space R^{2n} was further developed.

New science-based developments in the theory of geometric design and interval geometry provide a solution to the important applied problem of accounting errors in modeling and solving optimization problems of geometric design.

The proposed tools for mathematical modeling and solving interval optimization placement problems were used in developing computer programs: “PackingofIntervalParallelepipeds”, “PackingofIntervalPolygons”, “Simulation of alloy properties”.

Keywords: geometric design, interval geometry, interval mathematical model, optimization.

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METHODS OF BUILDING MATHEMATICAL MODELS OFACTUARIAL PROCESSES (p. 27-35)

Svitlana Trukhan, Petro Bidyuk

We have suggested a set of methods for designing mathematical models ofactuarial processes and an algorithm for evaluating unknown parameters with application of the Bayesian approach. The generalized linear models that represent expansion of the linear regression in cases when distribution of random variables differs from the norm are used as mathematical tools. This facilitates a detailed description of the structure and content of the researched model.

Real statistical data on the losses in the car insurance industry and the suggested methods have laid the basis for building a prognostic model of the actuarial process. A model using the Poisson distribution law and exponential function of communication has proved to be suitable for future use. It is confirmed by a minimal error magnitude and reliable estimates of parameters of generalized linear models obtained with the use of the Bayesian approach. We have determined that the normal model with anidentical connection function allows obtaining a result within one iteration with a slight relative errorbut with inaccurate predicted values of losses. Further studies require solution of the following tasks: analyzing and usinga set of risk factors that impact insurance cases, applying methods of intellectual data analysis in modeling, and forecasting actuarial processes.

Keywords: generalized linear models, connection function, remains, Monte Carlo methods, the Bayesian approach.

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AN ADEQUACY CRITERION IN EVALUATING THE EFFECTIVENESS OF A MODEL DESIGN PROCESS (p. 36-41)

Alexander Trunov

We have considered the process of building a mathematical modelas a technological operation whose effectiveness is evaluated by a unified method. The presented indices of the lowest effectiveness level of the process of building the arbitrary mathematical model can serve as a measurement for comparing their adequacy. We have modeled the process of the mathematical model building by means of the least squaresmethod and extra conditions.We have proved that the use of relative variables with a single measure(the greatest value of the variable in the interval) makes adequacy assessment insensitive to point releases, and in some cases it leads to erroneous conclusions in comparing models. We have suggested using relative variables with a local measure at each point. It is shown that this measure increases evaluation sensitivity to any point deviations in the model. The measure also corresponds to the model qualitative changes at decreasing or increasing relative deviations from boththe index of a separate derivative adequacy and its resulting valueat approximating the physical dimension and its derivatives.

Keywords: effectiveness evaluation, local measure, single adequacy criterion.

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HYBRID MATHEMATICAL MODELS AND METHODS FOR FORECASTING RELATED NONSTATIONARY TIME SERIES (p. 42-58)

Vitalii Shchelkalin

The paper presents mathematical models for forecasting related nonstationary time series and methods for their structural identification based on the joint use of a multidimensional variant of the "Caterpillar"-SSA method and VARMAX and SARIMAX models.

In the proposed hybrid mathematical models, using formulas for L- or K-continuation of multi-dimensional variant of the "Caterpillar"-SSA method, structural and parametric identification of the transfer function, connecting the endogenous and exogenous time series is carried out. Decomposition approach to time series forecasting based on multi-dimensional variant of the "Caterpillar"-SSA method and SARIMAX models lies in decomposition of source endogenous and exogenous time series into multiple time series with a simpler structure using the multidimensional "Caterpillar"-SSA method; forecasting data of decomposition components by SARIMAX models and calculating the total forecast for each endogenous time series, combining forecasts, constructed for simplified models.

The proposed models were tested on the example of forecasting physical parameters of the natural gas consumption processes of the linear parts of the gas transportation system, and the forecasting results were compared with the results, obtained by the VARMAX models. Experimental results show the high efficiency of the proposed forecasting models for selecting suitable structural parameters in comparison with the VARMAX models.

The results lead to the conclusion that for effective forecasts, it is necessary to perform the decomposition of the studied time series and combine different models, describing both statistical and deterministic time series components, which provides better forecasting.

Keywords: forecasting, structural identification, decomposition model, Box-Jenkins method, "Caterpillar"-SSA method.

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DEVELOPING METHODS FOR INVESTIGATING STABLE MOTIONS IN LOTKA-VOLTERRA SYSTEMS WITH PERIODIC PERTURBATIONS (p. 58-61)

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Destabilization effects of trophic coexistence of two populations, described by the Lotka-Volterra differential equation system at weak sinusoidal external influences on the reproduction rate were investigated. The stability of such a non-autonomous system was examined. Numerical solutions at frequencies of exposure close to the frequency of the cycle of the unperturbed system were found.

Such systems are soft classical models of many real objects in the ecology, economy and other areas, therefore their studies are relevant.

It is known that such systems of nonlinear equations with the perturbed right side generally can not be solved. Numerical experiment has allowed to reveal bifurcations when changing the amplitude n, and the perturbation period . Trophic parameters of the unperturbed system, as it is known for the classical Lotka-Volterra system do not lead to bifurcations.

As a result of the research, it was found that the amplitude variations (within 1±0.05) lead to a transition of the system from periodic motions to sustainable growth, and then to chaotic oscillations. At the same time, Lyapunov exponents may have opposite signs. So bifurcation introduces an asymmetry and instability in the structure of the characteristic exponents, and trajectory "goes" to infinity. Herewith, both monotonous and chaotic types are possible.

Keywords: Lotka-Volterra model, model perturbations, stability problems, periodic solutions, attractor, limit cycle.

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DEVELOPMENT OF THE MODEL OF NATURAL EMERGENCIES IN DECISION SUPPORT SYSTEM (p. 62-69)

Marina Zharikova, Volodimir Sherstjuk

In a modern anti-emergency DSS the required performance can be achieved using a plausible formal emergency model with the approximate nature of the undermined contour borders, which will significantly reduce the requirements for propagation model accuracy without substantial simplify it and without loss of clarity and justification for the decision-maker.

The formal emergency model is based on a territorial system resulting from the space (area) decomposition for a finite set of non-overlapping homogeneous regions (geotaxons) and subsequent sampling grid cells of equal size, which allows us to consider the dynamics of emergency spread discretely at the level of individual cells.

The emergency model includes the territorial system and the set of independent point sources, defined at the cells level of the territorial system, each of which forms a breeding ground for emergencies. The dynamics of emergency spread is simulated as the undermined contour borders motion in time represented with the approximate boundary region set using the rough set methodology.

Experimentally proved that the proposed emergency model provides acceptable performance in terms of DSS accuracy and compute speed at the sampling terrain cells with sizes ranging from 8 to 14 m.

Keywords: emergencies, territorial system, emergency contour spread, approximate contour borders, emergency source, geotaxon, cell.

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