ABSTRACT AND REFERENCES

MATHEMATICS AND CYBERNETICS – APPLIED ASPECTS

DOI: 10.15587/1729-4061.2017.108285

DEVELOPMENT OF THE DESCRIPTIVE BINARY MODEL AND ITS APPLICATION FOR IDENTIFICATION OF CLUMPS OF TOXIC CYANOBACTERIA (p. 4-11)

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In the paper, a descriptive model of system dynamics for binary data is presented. Binary or dichotomous data are widely spread across various fields of research – in decision making and data mining, marketing, solving of many natural, social and technical problems. The initial data for building the model is a set of states of an autonomous dynamical system with components taking binary values. At the same time, the time order of the states is permissible. The following objectives were stated: to identify the relationships between the components of the system defining its dynamics; on the basis of the identified dynamics, to recover the true order of the system states; to apply the developed model to the problem of visual identification of cyanobacteria in water areas using digital photography.

To solve the problem, we used a mathematical model that enables to describe the relationships between components and transitions between the system states at a simple-for-understanding level. The principle of parsimony underlies the model. According to this principle, the most appropriate model is described by the simplest relations in the sense defined in the work.

As the case study, the problem of recognizing clumps of cyanobacteria from digital satellite imagery was considered. This is a complex, practically important problem that does not have a satisfactory experimental and theoretical solution at the moment. Applying system approaches to the measured colorimetric parameters of digital photography, we developed the index for identification of such clumps. This index uses the parameters of the digital RGB model of (various parts of) an image and allows us to reveal clumps of cyanobacteria on digital images obtained by aerospace methods. Additionally, digital photography can be performed in the conditions of insufficient visibility (due to precipitation, fog, and other factors), for imitation of which in the case study the original image was distorted by the digital noise.

The studied model can find useful applications in the areas requiring binary dynamical data insights.

Keywords: descriptive models, dynamical systems, binary data, parsimony, data mining, clumps of toxic cyanobacteria.

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DOI: 10.15587/1729-4061.2017.107536

MODELS AND METHODS OF REGRESSION ANALYSIS UNDER CONDITIONS OF FUZZY INITIAL DATA (p. 12-19)

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The paper considers the problem of regression analysis with indeterminate explanatory and explained variables. A quality criterion for estimating the regression coefficients is formulated and justified, taking into account possible significant differences in the accuracy of assigning different variables. The study considers a method of calculating the regression coefficients in accordance with the concept of least squares. The proposed approach provides a reasonable compromise between the conflicting requirements: the maximum compactness of the fuzzy value function of the explained variable and the minimal deviation of the solution from the modal one. The problem is solved by minimizing the complex criterion, the terms of which determine the level of satisfaction of these requirements. An additional advantage of the approach is that the original problem, fuzzy by the nature of the initial data, is reduced to solving two usual problems of mathematical programming. The problem of fuzzy comparator identification is considered when the values of the explained variable are not defined but can be ranked by the descending of any chosen indicator. To solve this problem, the study proposes a method for estimating regression coefficients based on solving a fuzzy system of linear algebraic equations.

Keywords: fuzzy regression analysis, fuzzy initial data, fuzzy comparator identification.

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DOI: 10.15587/1729-4061.2017.108327

CONSTRUCTION OF INTERPOLATION METHOD FOR NUMERICAL SOLUTION OF THE CAUCHY'S PROBLEM (p. 19-27)

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An interpolation numerical method is developed in order to solve the Cauchy's problem for ordinary first order differential equations using the apparatus of non-classical minorants and diagrams of Newton's functions, assigned in a tabular form. We have proven computational stability of the method, that is, an error of the initial data is not piled up. It is also shown that the method possesses a second order of accuracy and in the case of a convex function produces more accurate results than the Euler's method. The advantages also include simplicity and visual clarity of the method. Given this, it could gain widespread use in many areas, in particular mathematics, physics and mechanics. We also give an example of solving the Cauchy's problem applying the new method, the Euler's method, and the Runge-Kutta fourth order method, with the results compared. The proposed method does not require solving the systems of linear algebraic equations because we do not employ the Bernstein polynomials, and it is not required to superimpose additional conditions, in contrast to the method that applies the Haar functions.

Keywords: Newton's minorant, differential equations, Cauchy's problem, Newton's diagram, convex function.

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DOI: 10.15587/1729-4061.2017.108413

DEVELOPMENT OF THE APPROACH TO PROVING THE SECURITY OF BLOCK CIPHERS TO IMPOSSIBLE DIFFERENTIAL ATTACK (p. 28-33)

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Trends in the development of symmetric cryptography are constantly associated with the increasing of the sizes of keys and blocks. Block ciphers, which are used today in hashing algorithms, usually have a block size of 512 or 1024 bits. One of the main requirements for symmetric crypto algorithms is to provide resistance to known cryptanalytical attacks. Known methods of security estimation against impossible differential attack have too high complexity for such block sizes.

The proposed approach for proving the absence of impossible differentials is applicable to some types of block ciphers and allows proving theoretically the resistance to impossible differentials attack.

Rijndael-like SPN ciphers and Feistel ciphers are analyzed. For the group of Rijndael-like ciphers, the absence of byte impossible differentials for 4 or more rounds is proved. For the group of Feistel ciphers, the absence of byte impossible differentials for 6 or more rounds is proved. The first statement made it possible to prove the absence of byte impossible differentials for 4 or more rounds of the cipher Kalyna (DSTU 7624: 2014) with all block sizes, for 512-bit block ciphers that are used in the hash functions Whirlpool, Groestl and Kupyna (DSTU 7564: 2014). The second statement was used to prove the absence of byte impossible differentials for 6 or more rounds of Tornado and Labyrinth ciphers with a block size of 128 bits.

Computational experiments on the impossible differentials search for these reduced models confirmed the validity of the obtained theoretical conclusions.

Keywords: block cipher, impossible differentials attack, impossible differential, Rijndael-like transformations.

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DOI: 10.15587/1729-4061.2017.108395

FEATURES OF MODELING FAILURES OF RECOVERABLE COMPLEX TECHNICAL OBJECTS WITH A HIERARCHICAL CONSTRUCTIVE STRUCTURE (p. 34-42)

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We developed a methodology and algorithms of forming the optimal sets of elements, which take part in the failure-recovery modeling process of complex technical objects. The methodology is based on the hierarchical constructive structure of the object, takes into account the redundancy of failing elements, as well as the maintainability of the product elements and their cost, which distinguishes this methodology from the known ones. Structurally, the methodology is implemented as a set of three algorithms. The generated optimal sets of elements are used to calculate the predictive reliability characteristics and operating costs of the object. The constructive structure of the object in the model is represented by a graph (tree). The optimality of the sets is understood in the sense of their correspondence to the object maintainability parameters.

With the improvement of maintainability properties, the forecasted values of the mean time between failures and the recovery time are correspondingly improved. Improvement of the operating cost index is not mandatory; provided different input data, there may not be such an improvement. Each variant of the values of object maintainability parameters is conformed to its optimal sets of failing and recoverable elements, under which adequate predictive estimates of reliability indicators and the object operating cost are provided.

The paper provides some examples of modeling, which demonstrate how the optimal sets of failing and recoverable elements are determined, and how the predictive estimates of reliability and object operating cost depend on the choice of these sets.

Keywords: complex technical object, hierarchical constructive structure, mean time between failures, unit operating costs, statistical simulation modeling.

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DOI: 10.15587/1729-4061.2017.108387

CRITERION OF THE CONTINUATION OF HARMONIC FUNCTIONS IN THE BALL OF n-DIMENSIONAL SPACE AND REPRESENTATION OF THE GENERALIZED ORDERS OF THE ENTIRE HARMONIC FUNCTIONS IN $\mathbb{R}^n$ IN TERMS OF APPROXIMATION ERROR (p. 43-49)

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A growth of harmonic functions in the whole space $\mathbb{R}^n$ is examined. We found the estimate for a uniform norm of spherical harmonics in terms of the best approximation of harmonic function in the ball by harmonic polynomials. An approximation error of harmonic function in the ball is estimated by the maximum modulus of an entire harmonic function in space, as well as the maximum modulus of an entire harmonic function in space in terms of the maximum modulus of some entire function of one complex variable or the maximal term of its power series. These results allowed us to obtain the necessary and sufficient conditions under which a harmonic function in the ball of an n-dimensional space, $n \geq 3$, can be continued to the entire harmonic one. This result is formulated in terms of the best approximation of the given function by harmonic polynomials. In order to characterize growth of an entire harmonic function, we used the generalized and the lower generalized orders. Formulae for the generalized and the lower generalized orders of an entire harmonic function in space are expressed in terms of the approximation error by harmonic polynomials of the function that continues. We also investigated the growth of functions of slow increase. The obtained results are analogues to classical results, which are known for the entire functions of one complex variable.

The conducted research is important due to the fact that the harmonic functions occupy a special place not only in many mathematical studies, but also when applying mathematical analysis to physics and mechanics, where these functions are often employed to describe various stationary processes.

Keywords: spherical harmonics, entire harmonic function, generalized order, lower generalized order.

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DOI: 10.15587/1729-4061.2017.108404

SYNTHESIS OF GENERALIZED NEURAL ELEMENTS BY MEANS OF THE TOLERANCE MATRICES (p. 50-62)

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Application of neuromorphic structures in various spheres of human activity on the basis of generalized neural elements will become possible if effective methods for verifying realizability of the logic algebra functions by one neuron element with a generalized threshold activation function and synthesis of such elements with a large number of edntries are developed. A notion of nucleus of Boolean functions in relation to a given system of characters was introduced and algebraic structure of nuclei and reduced nuclei of Boolean functions was investigated. Relation between the nuclei of the logic algebra functions which are realized by one generalized neural element and matrices of tolerance was established. It was shown that the Boolean function is realized by one generalized neuron element if and only if the nucleus of this function admits representation by the matrices of tolerance. If there is no nucleus relative to a specified system of characters for a Boolean function, then such a function is not realized by one generalized neural element in relation to a specified system of characters. On the basis of the properties of the matrices of tolerance, a number of necessary and sufficient conditions for realization of the logic algebra functions by one generalized neural element were obtained. Based on the sufficient conditions, an algorithm for synthesis of integer-valued generalized neural elements with a large number of entries was constructed. In the synthesis of integer-valued generic neural elements for realization of the logic algebra functions, a block representation of the Boolean function nucleus was used and based on the properties of the matrices of tolerance, coordinates of the integer vector of the structure of the generalized neural element were sequentially found.

Keywords: matrix of tolerance, nucleus of the Boolean function, group character, spectrum of the Boolean function.

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DOI: 10.15587/1729-4061.2017.108976

DESIGN OF THE UNIVERSAL CLASSIFIER AS A RBF NETWORK BASED ON THE CART SOLUTION TREE (p. 63-71)

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The aim of the paper was to develop a universal classifier in the form of a radial basis function network (RBF network) based on the Gaussian function and the CART Solution Tree. The examples of diseases diagnostics classifier were considered. It is noted that during the classifier development, it is necessary to determine the number of RBF neurons and the values of parameters of these neurons (centre, dispersion). For this purpose, a method that allows splitting the space of features into relatively homogeneous domains in the form of hyperparallelepipeds, each of which is associated with one of the RBF neurons, is proposed. The number of RBF neurons and parameters of these neurons are determined automatically directly based on the CART Solution Tree.

As a result of the research, it was found that the proposed classifiers show the highest efficiency on the learning set with a minimal Solution Tree reduction (accuracy from 80 % to 95 %). It was shown that for two and more classes the accuracy of these classifiers on the test set makes 79 % and more, however, provided that the appropriate data sample for the learning set is selected. The possibility of using the RBF network based on the Gaussian function and the CART Solution Tree in the healthcare system for the diseases diagnostics and medical systems (or devices) assistance during decision-making support was proved.

The obtained results could be further applied to improve the universal classifier development method based on the RBF network.

Keywords: universal classifier, neural network, RBF network, CART Solution Tree, decision-making support.

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