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DEVELOPMENT OF A METHODOLOGY FOR TRAINING ARTIFICIAL NEURAL NETWORKS FOR INTELLIGENT DECISION SUPPORT SYSTEMS (p. 6–14)

Oleg Sova
Military Institute of Telecommunications and Informatization named after Heroes of Kruty, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-7200-8955

Andrii Shyshatskyi
Central Scientifically-Research Institute of Arming and Military Equipment of the Armed Forces of Ukraine, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0001-6731-6390

Yurii Zhuravskyi
Zhytomyr Military Institute named after S. P. Koroliov, Zhytomyr, Ukraine
ORCID: http://orcid.org/0000-0002-4234-9732

Olha Salnikova
National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-7190-6091

Oleksandr Zubov
National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0001-9424-1689

Ruslan Zhyvotovskyi
Central Scientifically-Research Institute of Arming and Military Equipment of the Armed Forces of Ukraine, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-2717-0603

Igor Romanenko
Central Scientifically-Research Institute of Arming and Military Equipment of the Armed Forces of Ukraine, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0001-5339-7900

Yevhen Kalashnikov
National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0003-4552-6439

Artem Shulhin
State Aviation Research Institute, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-2403-7348

Alexander Simonenko
Military Institute of Telecommunications and Informatization named after Heroes of Kruty, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0001-8511-2017

The method of training artificial neural networks for intelligent decision support systems is developed. A distinctive feature of the proposed method is that it provides training not only of the synaptic weights of the artificial neural network, but also the type and parameters of the membership function. If it is impossible to provide the specified quality of functioning of artificial neural networks due to the learning of the parameters of the artificial neural network, the architecture of artificial neural networks is trained. The choice of architecture, type and parameters of the membership function is based on the computing resources of the tool and taking into account the type and amount of information supplied to the input of the artificial neural network. Due to the use of the proposed methodology, there is no accumulation of errors of training artificial neural networks as a result of processing information that is fed to the input of artificial neural networks. Also, a distinctive feature of the developed method is that the preliminary calculation data are not required for data calculation. The development of the proposed methodology is due to the need to train artificial neural networks for intelligent decision support systems in order to process more information with the uniqueness of decisions made. According to the results of the study, it is found that the mentioned training method provides on average 10–18 % higher efficiency of training artificial neural networks and does not accumulate errors during training. This method will allow training artificial neural networks through the learning of parameters and architecture, identifying effective measures to improve the efficiency of artificial neural networks. This methodology will allow reducing the use of computing resources of decision support systems and developing measures aimed at improving the efficiency of training artificial neural networks; increasing the efficiency of information processing in artificial neural networks.

Keywords: artificial neural networks, training, efficiency, information processing, intelligent decision support systems.

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DEVELOPMENT AND ANALYSIS OF GAME-THEORETICAL MODELS OF SECURITY SYSTEMS AGENTS INTERACTION (p. 15–29)

Serhii Yevseiev
Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-1647-6444

Oleksandr Milov
Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-6135-2120

Stanislav Milevskyi
Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-5087-7036

Oleksandr Voitko
National Defence University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-4610-4476

Maksym Kasianenko
National Defence University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-3749-4441

Yevgen Melenti
Juridical Personnel Training Institute for the Security Service of Ukraine Yaroslav Mudryi National Law University, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-2955-2469

Serhii Pohasii
Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-4540-3693

Hrygorii Stepanov
National Defence University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-9190-2821

Oleksandr Turinskyi
Ivan Kozhedub Kharkiv National Air Force University, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-6888-6045

Serhii Faraon
National Defence University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-5500-7352

A game-theoretic approach is presented, which claims to be a universal method for solving most problems in the field of cybersecurity. As arguments to confirm the superiority of game theory, mathematical validity and provability of the optimality of decisions made, unlike the widely used heuristics, the possibility of developing reliable protection based on analytical results, ensuring a timely response to cyberattacks in conditions of limited resources, as well as distributed nature of decision making are highlighted.

The definitions of the basic concepts used in security tasks based on game-theoretic models are introduced.

The features of the application of game theory methods in the field of cybersecurity are listed and the limitations of research in this area are formulated, namely: a restriction on game strategies, simultaneous moves of players in the behavior patterns of security system agents, uncertainty in the time the players take the move, uncertainty in the final goal of the enemy, unpredictability of further player moves, lack of players' assessment of enemy resources. as well as its ultimate goals, the inability to timely assess the current state of the game.

The game-theoretic models are aligned with the listed security problems, and the main solutions obtained as a result of using the corresponding models are also determined.

Many methods of game theory have been formed, for each of which a relationship is determined between the game model, its scope, simulation result and security services that the method under consideration supports.

The limitations of the classical representation of game theory models are determined, the need to overcome which follows from the requirements for providing basic security services. Such limitations include: the ability of the defender to detect attacks, the certainty of the probabilities of a change of state before the start of the game, the synchronism of the players' moves, the inability to scale the model due to the size and complexity of the system under consideration.

Models of the main tasks of the interaction of antagonistic agents of security systems have been developed. The resulting models made it possible to obtain solutions to two of the most common tasks in the field of cybersecurity, namely, the interaction of the system administrator and the attacker in organizing the protection of information resources. The tasks are solved for various conditions – the game matrix contains cost estimates of resources and the matrix reflects the probability of threat realization. Pure and mixed strategies are defined for various initial conditions, which allows to exclude from the consideration strategies that are not included in the solution.

A synergistic approach to the use of game-theoretic modeling was formed taking into account the behavior of agents of security systems, based on an analysis of the diversity and characteristics of game-theoretic models, their inherent limitations and scope.

Keywords: game theory, cybersecurity, Stackelberg games, Nash games, game equilibrium, strategy.

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THE MODELS OF ANTHROPOGENIC EMERGENCIES FOR DECISION SUPPORT SYSTEMS (p. 30–37)

Vadim Yakovenko
University of Customs and Finance, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0001-7762-5410

Yuliia Ulianovska
University of Customs and Finance, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0001-5945-5251

Tetiana Yakovenko
Dnipro University of Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0003-1900-8283

This paper addresses the issues related to controlling and preventing anthropogenic emergencies. The early detection of critical conditions, the accuracy, and reliability of monitoring system parameters is the key to the prevention of anthropogenic catastrophes of different levels.

A model of the emergency as a fuzzy situation has been proposed, based on the theory of fuzzy sets and the concept of a linguistic variable; a set of indicators has been determined that fully describe the factors affecting emergency. The set of indicators is a combination of both quantitative and qualitative data. It has been shown that the proposed fuzzy model is consistent with the characteristics and conditions of emergency occurrence at the objects of critical infrastructure and, at the same time, makes it possible to process both quantitative and qualitative indicators. This approach enables using fuzzy relations to form the similarity groups and to build rule bases in the decision support systems taking into consideration the similarity of situations, which improves the effectiveness of decision support systems.

Under extreme conditions, prompt and qualified managerial decision making is the most important task, which is solved, in particular, by the decision support systems. Since the construction of a rule base for an intelligent system requires the participation of experts, this paper has proposed a method for representing and processing expert data, which makes it possible to define the characteristics of their consistency and to choose the appropriate processing method. The proposed approaches to modeling emergencies could make it possible to detect situations in order to control and prevent them and to devise a set of activities in the case of an emergency, which would save human life and natural resources.

Keywords: emergency, fuzzy situation, expert information, decision support systems.

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FORMING A METHOD FOR DETERMINING THE COORDINATES OF SOUND ANOMALIES BASED ON DATA FROM A COMPUTERIZED MICROPHONE SYSTEM (p. 38–50)

Alexander Trunov
Petro Mohyla Black Sea National University, Mykolaiv, Ukraine
ORCID: http://orcid.org/0000-0002-8524-7840

Zhan Byelozyorov
Petro Mohyla Black Sea National University, Mykolaiv, Ukraine
ORCID: http://orcid.org/0000-0002-3216-8153

Special features in the process of determining the coordinates of sound anomalies according to the sound series were considered. Sound anomalies have been shown to be a source of information about events, phenomena that are already occurring, or are their harbingers. It has been stated that audio interception systems complement thermal imagers and provide savings in financial and human resources when used in combination with the benefits of unmanned aerial vehicles. The methods facilitating solution of the problem of surveillance and prediction by finding coordinates of sound anomalies were presented. Indirect methods for solving problems of searching for sound anomaly coordinates with three microphones in accordance with a linear scheme of approximants and linear and quadratic approximation were proposed. Solutions were reduced to analytical complete expressions that make it possible to calculate coordinates according to the input conditions for three or four microphones. Also, a problem of finding coordinates of a sound anomaly for three and four microphones was set and solved by direct methods. Solutions were presented as expressions that make it possible to calculate coordinates of sound anomalies. Numerical experiments were performed during which coordinates of sound anomalies, the absolute error of their determination at each iteration, and total time spent for calculation were found. Systems with coordinates of microphones and sound sources almost identical or coinciding have been shown to have the greatest error. Under these conditions, for direct methods, values of the equation coefficients decreased to almost zero or turned to zero and the difference of values of the sought coordinates between iterations increased sharply which slowed down the process of solution convergence. It was shown that the application of approximate methods to the search for coordinates by solving the minimization problems with the involvement of the recurrent approximation method makes it possible to construct simple algorithms. Their implementation to solve the problems of numerical experiments has given quick and practically accurate coordinate values. It was found, that the application of algorithms to the methods of logical analysis and rules of logical inference reduces the number of iterations and the total calculation time.

Keywords: sound anomaly, functional, recurrent approximation, analytical solutions, numerical experiment.

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CONSTRUCTING A METHOD FOR THE GEOMETRICAL MODELING OF THE LAME SUPERELLIPSES IN THE OBLIQUE COORDINATE SYSTEMS (p. 51–59)

Valeriy Borisenko
Mykolaiv V. O. Sukhomlynskyi National University, Mykolaiv, Ukraine
ORCID: http://orcid.org/0000-0002-0857-0708

Serhiy Ustenko
Odessa National Polytechnic University, Odessa, Ukraine
ORCID: http://orcid.org/0000-0003-4968-1233

Iryna Ustenko
Admiral Makarov National University of Shipbuilding, Mykolaiv, Ukraine
ORCID: http://orcid.org/0000-0003-1541-2414

The elliptic curves possess a certain disadvantage related to that at the point of intersection with the coordinate axes the ellipses have tangents perpendicular to these axes. However, such a situation is undesirable for some practical applications of ellipses. It can be prevented by modeling the specified curves in oblique coordinates, which, in turn, are related to a certain original Cartesian coordinate system. The Lamé superellipses are understood to be the curves whose equations include the exponents that differ from those inherent in regular ellipses. Variating these exponents can produce a wide range of different curves. This paper has proposed a method for the geometric modeling of superellipses in the oblique coordinate systems. The source data for modeling are the coordinates of the two points with the known angles of the tangent slope. The accepted axes of the oblique coordinate system are the straight lines drawn as follows. Through the first point, a line parallel to the tangent at the second point is built, and at the second point, a line parallel to the tangent at the first point is constructed. It has been shown that these operations could yield the desired values of tangent angles at intersection points of the superellipse with axial lines. It has been proven that the superellipse arc could be drawn through a third given point with the required angle of the tangent; that, however, would require determining the exponents in the superellipse equation by a numerical method. Such a situation occurs, for example, when designing the projected profiles of axial turbine blades. Based on the proposed method of modeling the superellipse curves, a computer code has been developed that could be used in describing the contours of components applied in the technologically complex industries.

Keywords: Lamé superellipse, geometrical modeling, oblique coordinate system, angle of inclination of the tangent, curvature distribution.

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IMPROVEMENT OF THE BRANCH AND BOUND ALGORITHM FOR SOLVING THE KNAPSACK LINEAR INTEGER PROBLEM (p. 59–69)

Elias Munapo
North West University, Mafikeng, South Africa
ORCID: http://orcid.org/0000-0001-6279-3729

The paper presents a new reformulation approach to reduce the complexity of a branch and bound algorithm for solving the knapsack linear integer problem. The branch and bound algorithm in general relies on the usual strategy of first relaxing the integer problem into a linear programming (LP) model. If the linear programming optimal solution is integer then, the optimal solution to the integer problem is available. If the linear programming optimal solution is not integer, then a variable with a fractional value is selected to create two sub-problems such that part of the feasible region is discarded without eliminating any of the feasible integer solutions. The process is repeated on all variables with fractional values until an integer solution is found. In this approach variable sum and additional constraints are generated and added to the original problem before solving. In order to do this the objective bound of knapsack problem is quickly determined. The bound is then used to generate a set of variable sum limits and four additional constraints. From the variable sum limits, initial sub-problems are constructed and solved. The optimal solution is then obtained as the best solution from all the sub-problems in terms of the objective value. The proposed procedure results in sub-problems that have reduced complexity and easier to solve than the original problem in terms of numbers of branch and bound iterations or sub-problems.

The knapsack problem is a special form of the general linear integer problem. There are so many types of knapsack problems. These include the zero-one, multiple, multiple-choice, bounded, unbounded, quadratic, multi-objective, multi-dimensional, collapsing zero-one and set union knapsack problems. The zero-one knapsack problem is one in which the variables assume 0 s and 1 s only. The reason is that an item can be chosen or not chosen. In other words there is no way it is possible to have fractional amounts or items. This is the easiest class of the knapsack problems and is the only one that can be solved in polynomial by interior point algorithms and in pseudo-polynomial time by dynamic programming approaches. The multiple-choice knapsack problem is a generalization of the ordinary knapsack problem, where the set of items is partitioned into classes. The zero-one choice of taking an item is replaced by the selection of exactly one item out of each class of items.

Keywords: knapsack integer problem, reformulation, branch and bound algorithm, unimodular, computational complexity.

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