Taras Shevchenko National University of Kyiv (Ukraine),
University of Defence, Brno, Czech Republic,
Glushkov Institute of Cybernetics of NAS of Ukraine,
Higher School Academy of Sciences of Ukraine,
Ivan Franko National University of Lviv, Ukraine,
Noosphere Ventures Corporation (Ukraine),
European Education Center (Georgia)

XXXIX International Conference PROBLEMS OF DECISION MAKING UNDER UNCERTAINTIES (PDMU-2024)

September 9 – 10, 2024

ABSTRACTS

Dedicated to the 190th anniversary of Taras Shevchenko National University of Kyiv

Brno, Czech Republic

Kyiv
2024

УДК 007 (100)(06)
ББК 32.81я43
Надруковано за рішенням Вченої Ради факультету комп'ютерних наук та кібернетики Київського національного університету імені Тараса Шевченка
(протокол № 17 від 28 червня 2024 р.)

INTERNATIONAL PROGRAM COMMITTEE
Prof. O. Nakonechnyi (Ukraine) – Chairman,
Prof. S. Aliev (Azerbaijan Republic),
Prof. S. Bekešienė (Lithuania),
Prof. M. Bratiychuk (Poland),
Prof. G. Chachanidze (Georgia),
Prof. A. Chikrii (Ukraine),
Prof. I. Didmanidze (Georgia),
Prof. L. Hampelová (Czech Republic)
Prof. N. Ibrahimov (Azerbaijan Republic),
Prof. T. Ivanov (USA),
Prof. J. Michalek (Czech Republic),
Prof. I. Sergienko (Ukraine),
Prof. Z. Suraj (Poland),
Prof. G. Yagub (Republic of Turkey)

NATIONAL ORGANIZING COMMITTEE

J. Drozd (Czech Republic) – Chairman,
M. Sedlačík (Czech Republic) – Co-Chairman,
M. Bartish (Ukraine), Ya. Chabanyuk (Ukraine),
I. Dyyak (Ukraine), O. Iksanov (Ukraine),
I. Khanin (Ukraine), O. Kapustian (Ukraine),
S. Lyashko (Ukraine), S. Mashchenko (Ukraine),
V. Marcenyuk (Ukraine), J. Neubauer (Czech Republic),
V. Romanenko (Ukraine), I. Rozora (Ukraine),
N. Semenova (Ukraine), S. Shakhno (Ukraine),
O. Tymashov (Ukraine), Ya. Yeleyko (Ukraine)

LOCAL ORGANIZING COMMITTEE

P. Zinko (Ukraine)– Chairman,
K. Hasilová (Czech Republic), U. Khimka (Ukraine),
T. Korobko (Ukraine), V. Lacinová (Czech Republic),
M. Losieva (Ukraine), O. Lukovych (Ukraine),
A. Nikitin (Ukraine), M. Šmerek (Czech Republic),
T. Zinko (Ukraine)

ISBN 978-617-555-228-5

190th ANNIVERSARY OF TARAS SHEVCHENKO NATIONAL UNIVERSITY OF KYIV

Taras Shevchenko National University of Kyiv is a research university with a classic tradition and is the leading establishment of higher education in Ukraine. The inauguration of the university was on July 15, 1834, the Memorial Day of Saint Prince Volodymyr. In the first academic year (1834-1835), only the faculty of philosophy worked at the university with two departments: historical-philological and physical-mathematical. 62 students were enrolled in the first year, and on August 28, 1834, classes began at the university.

Over the years of its existence, the University developed and grew, new departments and faculties were opened. There are 12 Faculties within the University: Chemistry, Computer Science & Cybernetics, Economics, Geography, History, Information Technology, Mathematics & Mechanics, Philosophy, Physics, Psychology, Radio Physics & Electronics & Computer Systems, Sociology. There are 11 Institutes: Educational and Scientific Center "Institute of Biology and Medicine", Educational and Scientific Institute "Institute of Geology", Educational and Scientific Institute of High Technology, Educational and Scientific Institute of International Relations, Educational and Scientific Institute of Journalism, Educational and Scientific Institute of Law, Educational and Scientific Institute of Philology, Educational and Scientific Institute of Public Administration and Civil Service, Institute of Continuing Education, Institute of Management State Guard of Ukraine, Military Institute.

The University awards Junior Specialist's, Bachelor's, Specialist's and Master's degrees, Higher Qualification Post-graduate degrees and Doctoral degrees. Training and retraining programs are provided in 14 specialties of Junior Specialist qualification, 55 fields of Bachelor training programs, 49 areas of Specialist training programs and 98 fields of Master training programs. Overall, about 26 thousand students and students of a military school, 1 660 postgraduate students and about 130 PhD students are working for higher qualifications at the University.

Over the years of its existence, the University has always actively participated in state-building processes in Ukraine, introduced innovative and intellectual ideas into the development of science and society. During the war with the terrorist country, the University works together with the people of Ukraine for Victory. Vivat Academia!

CONTENT[1]

Akhvlediani N. Importance of computer technology in foreign language learning 12

Akhvlediani Z. Scientific-technical texts and lexicography 13

Aliyev S., Khalilov V.S. On convergence of Bellman –Harris processes to continuous state space branching process. 14

Aliev S. A., Lysetskyi T.B., Yeleyko Ya.I. Stochastic additive functionals of multitype age-dependent branching processes 16

Androshchuk M. Efficiency of question-answering pipeline in systems with combined LLM and knowledge base usage 17

Bagrationi I. O. The impact of value theory on the decision-making in digital education 18

Bakhrushyn O. The use of intelligent computing for the analysis of educational data 21

Bakhrushyn V. Validity of evaluation indicators in complex educational systems 22

Bakhtadze Sh. On the Chogoshvili's spectral homology theory of the second family 23

Bartish M.Y, Kovalchuk O.V, Ohorodnyk N.P. On some Steffensen method modifications for solving non-linear equations 25

Benner P., Chuiko S., Nesmelova O. Conditions of solvability of nonlinear boundary value problems unsolved with respect to the derivative 26

Beyko I.V. Optimization problems in game processes 27

Beyko I.V., **Kuzma O.V.** Optimization problems in modern machine learning 28

Beyko I.V., **Spivak Yu.V.** To the construction of generalized optimal phase trajectories 29

Bezuevska O., Kapustian O., Bekesiene S. Group decision-making based on the aggregated analytic hierarchy process 30

[1] *The abstracts are publishing in authors edition*

Boichuk O., Chuiko S., Chuiko V. Inverse problems for nonlinear boundary-value problems with delay.....31

Bomba A.Ya., Turbal Y.V., Turbal M.Y., Smirnov D.A., Turbal B.Y. Forecasting methods based on polynomial extrapolation set analysis.....32

Bratiichuk M., Usar I. Optimal two-threshold strategy for a finite retrial queue.....33

Bychkov O., Merkulova K., Pavliukh B. Biometric identification in conditions of uncertainty of the possibility of identification.....34

Bychkov O., Merkulova K., Poliovyi A. Decision making in object detection on UAV imagery.....35

Chabaniuk Ya.M., Khimka U.T., Lytvyn A.A. The control problem for a diffusion model of epidemic with semimarkov switching.....36

Chabanyuk Ya.M., Khimka U.T., Semenyuk S.A. Asymptotic properties of the stochastic evolution under Markov-modulated Poisson perturbations 37

Chabanyuk Ya.M., Nikitin A.V., Chypurko R.A. Control problem generator for a diffusion process in a Lévy scheme within a semi-Markov environment 38

Chabanyuk Ya. M., Stepaniak O. B. Onvergence of the procedure of stochastic approximation of the Shaikhet–Santonjia model with semi-Markov switches.....39

Cheherst I.R. Machine learning models for decision-making under uncertainty: tracking sanction violations amidst the russian invasion of Ukraine 40

Chukhrai L., Nakonechnyi O., Chukhrai V., Loseva M. Guaranteed linear mean square estimates of the average value of random processes.....40

Degtyar S.V., Shusharin Yu.V. Partial moment equations for linear differential equations with random coefficients and random jumps of solutions.....41

Didmanidze D.Z., Putkaradze N., Zoidze N.M. Computer teaching systems and learning process.....45

Didmanidze I.Sh., Tsitskishvili G.D., Didmanidze Marina I., Imnaishvili G.T. The impact of information tecnologies on the decision-making in social activities.....46

Didmanidze Manana, Motskobili Ia, Solomonidze Anzor. Problems of employment and unemployment 49

Dolenko G., Manovytska D., Korobchuk M. Optimization of working capital flow 50

Drebot A. Mixture of Hidden Markov Models for data analysis.....51

Drin I., Drin S., Drin Y., Lutskiv M. Non-classical boundary value problem for the heat conduction equation 52

Drin I., Drin S., Drin Y., Lutskiv M. Study of numerical and analytical solutions of a generalized boundary value problem for the heat conduction equation.....53

Dutsko R. Artificial intelligence is a key technology of the fourth industrial revolution.....55

Dzhalladova I., Bartash O. Modeling algorithms for responding to information about corruption in social networks in the business sphere.....56

Dzhalladova I., Stefiienko A. Modeling response algorithms to cyber threats in critical infrastructures of the business sector 57

Eresko V., Vyshinskiy V., Vyshinskaya A., Kononenko A., Slipets A. On the application of internet of things in the development of computer systems for semi-nature modeling.....58

Fil B. AI as an expert in decision making 59

Gadjiev T.S. The apriori estimates and regularity of solutions the nonlinear elliptic equations in generalized Morrey spaces.....60

Galkin O., Anikanov O. Google Chrome browser extension for DXtrade trading platform for Forex 61

Givradze O., Didmanidze T. Regular elements of semigroup $B_X(D)$ defined by semilattices of class $\Sigma_2(X,4)$ 62

Grochowalski P., Suraj Z., Drygaś P. Petri net system in practice 63

Hnatiienko O., Hnatiienko H. The problem of ensuring the functional stability of organizational systems on ordinary scale under conditions of uncertainty 64

Hnatiienko V., Hnatiienko H. Minimizing uncertainty in forecasting sunflower yields associated with the presence of clouds in satellite images 65

Holubov H., Pashko A. Gamification of digital educational materials 66

Janelidze O.M., Takidze I.G. Initiation of electron capture by deep centers.....67

Kapustyan O., Zhuk T. Asymptotic analysis of optimal control problems on the semiaxes for Carathéodory differential inclusions with fast oscillating coefficients 68

Kashpur O. F. Interpolation and Kolmogorov-Gabor polynomials 69

Kharina A.O., Slabospitsky A.S. Solving the problem of tracking the penetration of objects into prohibited zones using machine learning....70

Khasaia Ia, Didmanidze I., Didmanidze D. Decision-making in a fuzzy environment: implications for educational issues.....71

Khudiakov A. Harnessing the industrial internet of things (IIOT) for advanced hardware-in-the-loop (HIL) simulation and digital twin optimization.....72

Khusainov D., Shatyrko A., Mustafaeva R. Estimations of solutions in dynamical systems with uncertain time-delay of neutral type 73

Kolba K.T., Prytula M.M. Exact solutions of one nonlinear dynamical system 75

Kolesnikov D., Semenova N. Optimization of the investment portfolio 76

Kotelnikova V., Iksanov O. A law of the iterated logarithm for small counts in Karlin's occupancy scheme.....78

Koval V.V., Lysenko V.P., Samkov O.V., Vakas V.I., Yanitskyi I.Ya., Piskun O.M., Kulesh O.V. Resilience of

synchronization means of electrical networks and telecommunication systems under the conditions of the military state.....79

Kovalenko O.Yu., Semenov V.V. Extragradient methods for variational inequalities with functional constraints.....80

Kudin G.I., Zinko T.P. Synthesis of hyperplane cluster in Euclidean space.....81

Kulian V., Korobova M., Yunkova O. Choosing of optimal portfolio structure.....82

Lebedeva T.T., Semenova N.V., Sergienko T.I. Regularization of vector mixed integer optimization problem.....83

Loseva M., Prishlyak A. Structure of optimal saddle-node bifurcations on the torus with a hole.....85

Luzan A. Development and implementation of a large language model assistant for mitigating cognitive biases in group decision-making.....87

Makushenko I., Usar I. About steady state distribution for retrial queues with hysteresis strategies.....87

Martsenyuk V., Soldatkin O., Kłos-Witkowska A., Sverstiuk A., Berketa K. Study on the operational stability of a lactate biosensor: modeling, parameter identification and stability evaluation.....89

Mashchenko S.O. On aggregation of expert assessments for a fuzzy set of decision-makers.....91

Merkulova K., Lybak I. Decision-making in the management of higher education institutions in fuzzy conditions.....92

Merkulova K., Spitsyn V. Computer intensive techniques for decision making in different fields.....93

Nakonechnyi O., Cherniy D., Dyyak I. Inverse problems for the equations of a weakly compressible fluid under conditions of uncertainty.....94

Nakonechnyi O.G., Mashchenko S.O. On balleans dynamics under fuzzy conditions.....95

Nakonechnyi O., Zinko P., Hnatyshko M. Estimation methods in observation problems under conditions of uncertainty.....96

Nakonechniy O., Zinko P., Zinko T. Guaranteed posterior estimates of solutions of operator equations 99

Oficerov A. Interconnected system of Riccati operator equations 104

Ogurtsov M. Method of mutual authentication of UAV swarm elements under uncertainties.....105

Osmak Y. Solving the problem of jobs prioritization under limited resources for the case of a service company.....106

Papunidze M. Decision-making under uncertainty: exploring consumer behavior and its implications in economics and business.....106

Pashko A., Bedzir O. AI approach for web real-time communication congestion control.....107

Peregontsev O. Wireless sensor networks for embedded systems. Overview of embedded systems 108

Petrivskyi V., Bychkov O. Automated decision making trajectory building system.....109

Pogorielov D. Estimation of parameters in economic models with generalizations.....110

Pokutnyi O., Iskra O. Branching solutions for the interconnected system of Lyapunov equations with control.....111

Polyakov M., Khanin I., Shevchenko G., Bilozubenko V. Intelligent data analysis in the 'knowledge economy' 112

Pylypenko A. Influence of explainable AI on the architecture of text classification models.....113

Romanenko V., Miliavskyi Yu., Kantsedal H. Constrained disturbances suppression for multirate impulse processes in cognitive maps of cryptocurrency applications.....114

Rozora I.V., Melnyk A. Statistical methods for impulse response function estimation in linear systems 115

Samnidze N., Diasamidze M. Speaking skills: evaluating the impact of the Diamond Method in EFL education 116

Samoilov S. Methods and algorithms of artificial intelligence in mobile medical complexes 117

Senio P.S. Two-sided methods for solving integral equations.....118

Semenov V.V., Kolesnikov D.S., Fateeva I.M. Decomposition method for solving partially discrete bilinear optimization problems.....119

Shabanov D. Analysis of available artificial neural networks as an assistant for creating computer programs.....120

Shakhno S.M., Yarmola H.P. On the Newton-Broyden method for solving systems of the nonlinear equations.....121

Shakotko T.I. Convergence of learning processes in discrete equations of neural networks dynamics.....122

Shcherbatyy M. Enhancing warfare strategies through Lanchester-type modeling and optimization.....123

Shchestyuk N., Tyshchenko S. Value-at-risk measuring for subdiffusion option pricing models.....124

Shevchuk I., Subotina A. Short-term forecasting of gas air using methods of system analysis.....125

Shkilniak O. S., Shkilniak S. S. Elimination of quantifiers in logics of partial non-monotonic quasiary predicates.....126

Shkilniak O. S., Shkilniak S. S. Sequent deduction systems in transitional modal logics of partial predicates.....127

Sihaiev I. Branching of soultions in the system of kinetic reactions..128

Sosnenko K., Samoliuk T. Means of decoding conversion codes in control systems and special purpose equipment.....129

Stetsenko I., Tretiakov Y., Vergunova I. The problem of aggregation, processing and analysis of internet traffic.....130

Stopchatyi A.V. Application of Bayesian inference in optimization problems with unknown objective function parameters.....132

Stoyan V., Voloshchuk S. Control problems of dynamics of thick elastic plates with a continuously specified desired condition.....132

Suchkov V.I., Pashko A.O. COVID-19 computed tomography image processing based on statistical segmentation methods.....134

Suraj Z., Grochowalski P., Drygaś P. Hybrid methods for modeling knowledge-based systems using PNeS.....135

Taraniuk D., Makhno M. Automatic structuring and analysis of physical addresses using BERT model.....136

Timashov E. Modern mobile medical and diagnostic complexes.....137

Tkach M. Analysis of the intervals between trains at a subway station using queueing modelling.....138

Tsinaridze R. A non-Abelian group of congruent numbers 139

Tsintsadze I., Asanidze T., Chkhikvishvili N. Spatial memory impairment in medial septal and dentate gyrus lesioned rats 140

Tymashov O. Wireless sensor networks and IoT for embedded systems 141

Tymofieva N.K. Solving artificial intelligence problems using combinatorics 142

Tupalo Y. Misuse of artificial intelligence for cyber attacks and counters data attacks in modern information systems.....143

Vasyliev O. Modeling the movement of elements with memory in an active environment 144

Vavryk R., Sokolovskyy Y. One method for estimating population displacement.....145

Voina O. Some algorithms of vector prognostication.....146

Vyshinskiy V., Vyshinska O., Kononenko O., Slipets A., Eresko V. Hardware for storing and processing a unit of information in matrix-algebraic computers.....147

Yakovliev Y., Kurzantseva L. Use of the internet of things in the development of an intelligent interface for semi-nature modeling systems 148

Yakovliev Y., Yelisieieva O. Performance metrics of IoT and AR interaction.....149

Yarova O.A. The bihaviour of multidimensional renewal equation ..150

Zhukovska O. Making credit decisions based on Bayesian strategies.....151

THE IMPORTANCE OF COMPUTER TECHNOLOGY IN FOREIGN LANGUAGE LEARNING

Neli Akhvlediani
Batumi Shota Rustaveli State University, Georgia

The integration of computer technology into foreign language learning has made significant progress in recent decades, opening up new possibilities for enhancing language proficiency. Computer-Assisted Language Learning (CALL) encompasses a wide range of applications, including language learning software, mobile apps, online courses, and interactive platforms. These technologies offer tailored learning environments that can adapt to the individual needs and learning styles of users.

A significant advantage of CALL is the accessibility and flexibility of learning. Learners can access learning materials anytime and anywhere, which is particularly advantageous for individuals with busy schedules or geographical constraints. Additionally, interactive features such as speech recognition, real-time feedback, and gamification create a more dynamic and motivating learning environment.

Furthermore, CALL promotes collaboration and communication among learners on a global scale. Platforms for virtual classrooms and social networks facilitate exchange and interaction with native speakers and other learners, leading to a more authentic and practical language practice.

Despite the numerous benefits, there are also challenges and limitations that need to be considered. Dependence on technological resources and the necessity of an internet connection can present barriers.

In summary, the combination of foreign language learning and computer technology has the potential to complement and expand traditional learning methods. By providing flexible, interactive, and collaborative learning opportunities, CALL can contribute to the development of language proficiency in a more effective and engaging manner. Future research and technological innovations are likely to bring further improvements and new approaches in this dynamic field.

SCIENTIFIC-TECHNICAL TEXTS AND LEXICOGRAPHY

Zeinab Akhvlediani
Batumi Shota Rustaveli State University, Georgia

Our era can confidently be termed the age of groundbreaking scientific and technological transformation. Nowadays, accessing international statistical databases and research findings is no longer a challenge. Translation is one of the means to ensure participation in the shared information space.

Theoretically, machine translation, which can now freely incorporate the comprehensive terminological data of various fields thanks to today's technological capabilities, should be able to accurately transfer factual information to the target language with meticulous precision and without emotional bias. However, translation experience has shown us that while it may be possible to select equivalent lexical units at some level during machine translation, we often encounter a range of other difficulties. These include grammatical inequivalence, which involves inadequate reflection of syntactic and morphological changes, inadequate handling of changes in word forms, arrangements, and word connections, inaccuracies in content representation, such as omitting the need to reflect a positive sentence as negative, and numerous other grammatical challenges. 2. The impossibility of interpreting the implicitness of subtext poses a significant challenge to the adequacy of machine translation, a sentiment with which all translators would likely agree.

The skills of the translator are a necessary condition for the adequate implementation of translation, as they encompass the competence needed to achieve semantic, grammatical, and pragmatic equivalence in translation.

To achieve adequate translation in the scientific and technical field, the translator's primary tool is often an encyclopedic dictionary equipped with a comprehensive terminological base.

Such dictionaries must necessarily feature extensive definitions of terms across various fields and include a wealth of ready-made examples. Such resources significantly facilitate the translator's work and ensure accurate translation through the correct application of terminology.

ON CONVERGENCE OF BELLMAN –HARRIS PROCESSES TO CONTINUOUS STATE SPACE BRANCHING PROCESS.

S. Aliyev, V.S. Khalilov
Ministry of Science and Education of the Republic of Azerbaijan,
Institute of Mathematics and Mechanics, Baku, Azerbaijan
Ministry of Science and Education of the Republic of Azerbaijan
Institute of Control Systems, Baku, Azerbaijan
soltanaliyev@yahoo.com

Let $\xi_n, n = 0,1,2,...$ be the number of particles in the *n*-th generation. If $\xi_{n+1} = \theta_1 + \theta_2 + ... + \theta_n, n \geq 0,$ where θ_i are independent random variables denoting the number *f* direct off springs of *i*-th particle, then we say that ξ_n is branching process with discrete time.

The discrete time branching process sometimes is called the Galton-Watson process.

The limit theorems on convergence of Galton-Watson processes to continuous state space branching process were obtained in the papers [1,2].

The Markov process $\mu(t)$ is called the continuous state space branching process in R_+ if $M\left[e^{-\lambda\mu''(t)} \mid \mu(0) = x\right] e^{-xK(t,\lambda)}$, where $x \in R_+, \lambda \geq 0$ and $K(t,\lambda)$ for every $t \geq 0$ is the logarithm of Laplace transformation of some infinitely divisible distribution in R_+.

In this work the similar results were obtained for Bellman-Harris branching processes.

Bellman –Harris processes differ from Galton-Watson processes only by that from the moment of appearance of particle to its conversion moment passes some random time called lifetime. Distribution of lifetime is the same for all particles and independent on the structure of population.

Let $\eta(t), t \geq 0$ be the number of particles of Bellman-Harris branching process at the moment $t(\eta(0) = 1)$. Distribution function of the lifetime of one particle *l* we denote $G(t) = P\{l \leq t\}$.

We suppose that $G(0-) = G(0+) \leq 1, \quad 0 < a = \int_0^\infty dG(t) < \infty.$

At the end of life the particle moves to *k*-new-bens of the particles $(k = 0,1,2,...)$ with probability p_k respectively. The number of particles

in 0,1,2,… generation of the process $\eta(t)$ is denoted by $\xi_0, \xi_1, \ldots$. It is known, that the variants $\xi_0, \xi_1, \ldots$ form the |Galton-Watson branching process with the generating function $F(s) = \sum_{k=0}^{\infty} p_k s^k, \quad |s \le 1|$.

Let $F(t,s)$ be the generating function of the number of particles in the Bellman-Harris branching process at the moment of time *t*

$$F(t,s) = \sum_{k=0}^{\infty} p\{\eta(t) = k\} s^k = M\left[s^{(\eta(t)} \,|\eta(0) = 1| \right]$$

Now we consider the sequence of the Bellman-Harris branching process $\eta^{(m)}(t) m = 1,2,\ldots, t \ge 0$ with generating function

$$F^{(m)}(t,s) = M\left[S^{\eta^{(m)}(t)} \,|\, \eta^{(m)}(0) = 1 \right]$$

and with sequence of the lifetime distribution function $G_m(t) = P\{l_m \le t\}$.

Denote $a_m = \int_0^{\infty} t dG_m(t) \le \infty$, $\lim_{m\to\infty} a_m = a$, $A_m = \left.\frac{dF^{(m)}(s)}{ds}\right|_{s=1}$.

We assume that there exists a finite positive limit

$$\frac{b^m_{[\tau t]}}{b^m_{(t/a)}} \text{ if } n = [t/a], t \to \infty, m \to \infty \quad n(1 - A_m) \to 0 \qquad \text{(A)}$$

where $b_n^m \to \infty$ as $n \to \infty, m \to \infty$.

Denote the sequence of the random processes $\mu_\tau^{(m)}(t) = \frac{\eta^{(m)}(\tau t)}{B_m(t)}$,

where $\mu_\tau^{(m)}(0) = \frac{[xB_m(t)]}{B_m(t)}$, $B_m(t) = b^m_{[t/a]}$.

Let $t \to \infty, m \to \infty. t(1 - A_m) \to 0.$ For same conditions on generating function $F^{(m)}(s)$ and of the lifetime distribution function $G_m(t)$ the limit theorem on convergence to continuous state space branch ing. process is proved.

References

1. Ryzhov Yu. M., Skorohod A.V. Homogeneous branching processes with a finite number of types of particles and everchanging mass. // Probability theory and appl. – 1970. – Vol. 15(4). – P. 722-726.

2. Aliyev S.A., Shurenkov V.M. Transitional phenomena and the convergence of Galton–Watson processes to Jiřina processes. // Probability theory and appl. – 1982. – Vol.27(3). – P. 443-455.

STOCHASTIC ADDITIVE FUNCTIONALS OF MULTITYPE AGE-DEPENDENT BRANCHING PROCESSES

S.A. Aliev[1], T.B. Lysetskyi[2], Ya.I. Yeleyko[2]
[1]Institute of Mathematics and Mechanics of NAS of Azerbaijan, Azerbaijan
[2]Ivan Franko National University of Lviv, Ukraine
soltanaliev@yahoo.com, yikts53@gmail.com
taras.lysetskyi@lnu.edu.ua

Consider multitype indecomposable age-dependent branching processes ξ and η, where latter denote process with immigration.

Suppose that each individual xi, i ∈ ℕ, during its lifetime, denoted as τ, generates some product. Let $\gamma_i(t)$, $t \le \tau$, represent the amount of product produced by an individual x_i over time t.

A stochastic additive functional from the branching process, denoted as $\zeta(t)$, can be defined as the sum of the product generated by all individuals that existed before time t. Additionally, the processes $\gamma_i(t)$, $t \le \tau$, corresponding to different individuals, are independent. For the same type, they are also identically distributed.

We prove, that for processes ξ, under condition of finiteness of second moments of $\gamma_i(t)$, the second moments of the number of descendants of x_i, and the finiteness of the first moments of τ, the functional $\zeta(t)$, normalized by t^2 and under the condition of non-extinction by t, converges in distribution to limit law, whose characteristic function is

$$\sqrt{c_1\theta} \,/\, sh(\sqrt{c_1\theta}),$$

where $\theta > 0$ and c_1 is positive constant.

For the processes η similar convergence takes place: characteristic function of limit law is

$$\left(ch\sqrt{c_2\theta}\right)^{-c_3},$$

where $\theta > 0$ and c_2 and c_3 are some positive constant.

References

1. Lysetskyi T.B., Yeleiko Ya.I. Limit theorems for total number of particles in critical age-dependent branching processes // Precarpathian Bulletin of the Shevchenko Scientific Society. – 2021. – №16(60). – P. 33–46 (in ukrainian).
2. Shurenkov, V.M. On additive functionals of branching processes // Theory of Probability and its Applications. – 1979. – №24(2). – P. 396-401.

EFFICIENCY OF QUESTION-ANSWERING PIPELINE IN SYSTEMS WITH COMBINED LLM AND KNOWLEDGE BASE USAGE

M. Androshchuk
National University of Kyiv-Mohyla Academy, Ukraine
maxym.androshchuk@ukma.edu.ua

The integration of a large language model (LLM) with a knowledge base (KB) has been shown to significantly enhance the efficiency of question-answering (QA) pipelines. The KnowledgeNavigator framework has demonstrated effectiveness and generalization in QA tasks [1].

However, there are challenges in this integration, such as the complexity of natural language and the richness of entities and relations in knowledge graphs [2]. Despite these challenges, novel approaches, show the potential of leveraging graphs to improve retrieval and generation processes [3].

Combining LLMs with KBs can lead to more efficient QA pipelines by utilizing the reasoning and few-shot learning capabilities of LLMs, as well as the structured information in KBs. This synergy shows promise in addressing the inherent complexities of natural language and knowledge representation by using context-relevant processing.

References

1. Guo, Tiezheng, Qingwen Yang, Chen Wang, Yanyi Liu, Pan Li, Jiawei Tang, Dapeng Li, and Yingyou Wen. 2023. "KnowledgeNavigator: Leveraging Large Language Models for Enhanced Reasoning over Knowledge Graph." arXiv. doi:10.48550/ARXIV.2312.15880.

2. Xiao, Yuliang, Lijuan Zhang, Jie Huang, Lei Zhang, and Jian Wan. 2022. "An Information Retrieval-Based Joint System for Complex Chinese Knowledge Graph Question Answering." Electronics. MDPI AG. doi:10.3390/electronics11193214.

3. Wang, Yu, Nedim Lipka, Ryan A. Rossi, Alexa Siu, Ruiyi Zhang, and Tyler Derr. 2024. "Knowledge Graph Prompting for Multi-Document Question Answering." Proceedings of the AAAI Conference on Artificial Intelligence. Association for the Advancement of Artificial Intelligence (AAAI). doi:10.1609/aaai.v38i17.29889.

THE IMPACT OF VALUE THEORY ON THE DECISION-MAKING IN DIGITAL EDUCATION

I. O. Bagrationi
Batumi Shota Rustaveli State University, Georgia
irma.bagrationi@bsu.edu.ge

The present scientific report deals with the principal and cardinal axiological viewpoints and positions of traditional theory of values, through metaethics and normative ethics, within the framework of Digital Education system in passing by decision-making process. The report is interested in the methodological approaches and usual understanding of value theory of an American professor in Philosophy at the University of Southern California Mark Schroeder. Through practical philosophy he points that "value theory" designates the area of moral philosophy that is concerned with theoretical questions about value and goodness of all varieties - the theory of value. The theory of value, so construed, encompasses axiology, but also includes many other questions about the nature of value and its relation to other moral categories" [5].

The report tells us that, first of all, we need to understand the traditional lexical meaning concepts of "Digital Education" which is often found in pedagogical literature and paroemiac regulatory documents. It is well known for us that the term "Digital Education" has several meanings: In a general sense, the term "digital education" is understood as "education" in the digital age, referring to all nuances of meaning "a spontaneously emerging cyber-socialized society with all its metaphysical and immanent features, and digital education specially organized in the intellectual world system" [1].

It seems that mental understanding the essence and characteristics of the "spontaneous" cyber socialization of society and a specific person in it should be fundamentally different from understanding the ethical factors and patterns of digitalization of education, just as the processes of assimilation of knowledge differ from their pragmatically application. In our opinion, the emergence of moral problems of digital education in the world and its literal "intoxication" occurred under the influence of some objective factors that almost coincided in time:

- Advances in cognitive sciences, claiming that the mechanisms of information processing by the human brain and the computer are identical phenomenon - called as "computer metaphor" or "Artificial Intelligence";
- Inheritance of the approach to valuable management, developed in the now forgotten creative programming modeling - the predecessor of digital

nature and “looking at topics such as oral histories of values” [3].

- The emergence of the intellectual industry of personal computers, a variety of digital devices and cybernetic equipment necessary for their virtual discursive operation;
- Competitive business pressure: all these intelligence must be sold, and the education system is an inexhaustible banal market, “the potential dangers of commercialized education are catching the attention of educators” [3].

The report is interested in the point of view of scientific work “For the Issues of the World-View Online Foreign Language Learning” by the way of metaethical categories: “Our research has been informed by a view that, to understand epistemological worldview mobilization, one has to abandon the traditional, narrow and utilitarian idea implicit in the concept of online utilizing education” [2], “as well as the cognate view that information behavior that are carried out over and above the practical duties of lecturer teachers” [2]. And by Georgian Professor Ibraim Didmanidze’s work “On the Ethical Values of Business and Technology Education according to Erich Fromm’s Social Pedagogy Views” this vision “implies a new ethical model of business education and management that integrates considerations of vocation, purpose, and values at a social-theological level” [4].

In the metaethical worldview context, the report outlines the use of a computer for cognitive educational purposes is carried out in three forms: a machine as a simulator; as a tutor who performs certain functions for the teacher, moreover, such that a machine can perform better than a person; as a device that simulates the environment and the action of students in it. It is advisable to use simulators to consolidate and systematize the skills and abilities already acquired. Tutoring systems are most useful when the tasks and conditions for using educational information are clearly defined and are not probabilistic. Simulation modeling is most suitable when the educational material is not of a systemic nature and its boundaries are rather vague. Obviously, in the first two forms, the computer acts only as a means of quantitatively enhancing the teacher's functions, increasing the speed of information exchange between the teacher and the student, the efficiency of decision-making, etc. And it is precisely these possibilities that they are trying, first of all, to use all over the world in the process of computerization of education. However, they do not give a qualitative change in the situation in education and, in principle, cannot give, since the same results, sometimes even with less time, human, moral and intellectual resources,

can be provided by traditional forms, methods and means of teaching. Accordingly, “the division of moral theory into the theory of value, as contrasting with other areas of investigation, cross-cuts the traditional classification of moral theory into normative and metaethical inquiry, but is a worthy distinction in its own right; theoretical questions about value constitute a core domain of interest in moral theory, often cross the boundaries between the normative and the metaethical, and have a distinguished history of investigation” [5].

The conclusion from all that has been said is obvious: a computer, in principle, is not capable of converting meanings into meanings, information into knowledge. This means that "computer metaphor" is nothing more than a symbol; information processing by a computer is not a mechanism for generating knowledge from it by a person, and it is necessary to look for ethical patterns and mechanisms for understanding this process.

References

1. Bagrationi I. For the Ethical Problems of Digital Education in Decision-Making Process // Proceedings of XXXVIII International Conference “Problems of Decision Making under Uncertainties” (PDMU-2023), Kyiv: “Видавництво Людмила”, 2023, p. 16-18. (In English) - URL: http://www.pdmu.univ.kiev.ua/PDMU_2023/PDMU-2023_End.pdf

2. Bagrationi I. For the Issues of the World-View Online Foreign Language Learning// Proceedings: “SGEM 2018” - 5th International Scientific Conference, Volume 5, Issue 2.2, Published by STEF92 Technology Ltd., 51, Sofia, Albena Co., Bulgaria. 2018. DOI: 10.5593/sgemsocial2018/2.2/S09.063\ - pp. 497-504. - URL: https://www.sgemsocial.org/index.php/elibrary-research-areas?view=publication&task=show&id=575

3. Didmanidze I., Bagrationi I. The Issue of Student Distance Communication and Collaboration// The Journal “Cross-Cultural Studies: Education and Science (CCS&ES)”, Vol. 3(I), Publisher: Beyer Thomas Robert, Published by “Middlebury College”, Vermont, USA, ISSN: 2470-1262, 2018, Pp. 6-19. (In English) - URL: http://j-ccses.org/wp-content/uploads/2018/06/Issue-1-2018.pdf

4. Didmanidze I., Beridze Z., Bagrationi I. On the Ethical Values of Business and Technology Education According to Erich Fromm’s Social Pedagogy Views // Proceedings: “SGEM 2019” - 6th International Conference, Volume 6, Issue 6.1; Sofia, Bulgaria. DOI: 10.5593/sgemsocial2019V/6.1/S07.007 - pp. 53-62. - URL:

https://www.ssalibrary.at/sgem_jresearch_publication_view.php?page=view&editid1=3832&
5. Schroeder M. Value Theory. - Stanford Encyclopedia of Philosophy, First published February 5, 2008; substantive revision March 4, 2021. - URL: https://plato.stanford.edu/entries/value-theory/

THE USE OF INTELLIGENT COMPUTING FOR THE ANALYSIS OF EDUCATIONAL DATA

O. Bakhrushyn
National University "Zaporizhzhia Polytechnic", Ukraine
o.bakhrushyn@gmail.com

Today, evidence-based decision-making is the main approach to making important decisions. Usually, such evidence must be based on reliable data. That is why various databases of different levels are constantly appearing and developing in the world. Among them there are: global multidisciplinary statistical bases such as UNESCO, Eurostat, OECD, World Bank dases; specialized educational bases such as European Tertiary Education Register, databases of university rankings, PISA data; national multidisciplinary and specialized databases such as data of State Statistics Service of Ukraine and Ukrainian center for educational quality assessment. The peculiarities of these databases are great datasets of complex structure, which contain data of various types and omissions. The same type of data in different databases may not be completely comparable, as they are often collected using different techniques, have some different content, refer to different moments of time, etc.

Therefore, the use of intelligent computing methods [1] is promising for the analysis of such data. In particular, this concerns the selection of informative combinations of features, including selection from different databases, the search for relations between features, the choice of optimal for specific conditions, tasks and decision-making methods based on available data, etc.

References

1. Oliynyk A. O., Subbotin S. O., Oliynyk O. O. Intelligent data analysis. – Zaporizhzhia: ZNTU, 2011. – 278 p.

VALIDITY OF EVALUATION INDICATORS IN COMPLEX EDUCATIONAL SYSTEMS

V. Bakhrushyn
National University "Zaporizhzhia Polytechnic", Ukraine
Vladimir.Bakhrushin@gmail.com

Education is not only an important social good, but also it is one of the key factors in the development of countries and civilizations. That is why reliable and valid evaluations are important for planning and forecasting the evolution of educational systems, making decisions about their modernization, designing new systems, etc. Usually, the integral evaluation indicators are not measured directly, but are constructed as a certain function from the values of selected individual indicators characterizing various properties of a complex systems. There are many examples of the use of multidimensional evaluations to solve various theoretical and applied problems related to educational systems. In particular, these are the problems of comparing the effectiveness of national educational systems, ranking universities, allocation of budget funding, projects evaluation, accreditation of higher education institutions and study programs, optimization of HEI networks, selection of applicants, etc. However, determining the validity of the estimates used is often neglected, which can lead to gross errors in decision-making.

The main sources of the estimates non-validity are:

1) not all the necessary components of the integral indicator were taken into account.
2) the structure of the integral indicator and/or the method of data normalization for its components were selected unsuccessfully.
3) numerical data for system evaluation are selected based on their availability rather than relevance.
4) available data are incomplete and/or measured with a large error.

An obligatory stage of the evaluation methodology should be the verification of the validity of the evaluations both by their theoretical justification and by analyzing the fitness of the results of their using for the purpose of evaluation.

ON THE CHOGOSHVILIS SPECTRAL HOMOLOGY THEORY OF THE SECOND FAMILY

Shalva Bakhtadze
Batumi Shota Rustaveli State University, Georgia

Let LP_2 be a category of pairs of locally compacted paracompact spaces and their proper mappings and $(X, A) \in LP_2$.

Locally finite open covering $\alpha_r = \left\{U_t^{(\alpha_r)}, t \in T^{(\alpha_r)}\right\}$ of a space X is called a regular covering, if the closures of its elements are compact in X.

Let denote induced by a covering α, a regular covering in the subspace A as α_r.

Let denote as

$$Cov^r(X, A) = \left\{\left(\alpha_r, \alpha_r\right) \| \alpha_r \in Cov^r(X)\right\}$$

the set of all regular coverings of the pair (X, A), and as $\left(N_\alpha, N_\alpha\right)$ a pair of nerves of the pair coverings $\left(\alpha_r, \alpha_r\right)$.

Each inscription $\left(\alpha_r, \alpha_r\right) \succ \left(\alpha_r', \alpha_r'\right)$ defines

$$\pi_{\alpha_r'}^{\alpha_r} : \left(N_{\alpha_r}, N_{\tilde{\alpha}_r}\right) \to \left(N_{\alpha_r'}, N_{\tilde{\alpha}_r'}\right) \tag{1}$$

the pairwise adjacent simplicial mappings.

Let $H_n^{inf}\left(N_{\alpha_r}, N_{\tilde{\alpha}_r}; G\right)$ and $H_f^n\left(N_{\alpha_r}, N_{\tilde{\alpha}_r}; H\right)$ $n-$dimensional homology and cohomology groups of all arbitrary (possible) cycles and finite cocycles of pairs of complexes $\left(N_{\alpha_r}, N_{\tilde{\alpha}_r}\right)$ with coefficients from groups G and H respectively.

Then these groups and the homomorphisms $\pi_{\alpha_r'*}^{\alpha_r}$ and $\pi_{\alpha_r'}^{\alpha_r *}$, induced by the mappings (1), are constitute the direct and inverse spectra respectively homological and cohomological groups and homomorphisms:

$$\left\{H_n^{inf}\left(N_{\alpha_r}, N_{\tilde{\alpha}_r}; G\right), \pi_{\alpha_r'}^{\alpha_r} \| \alpha_r, \alpha_r' \in Cov^r(X)\right\}$$

and

$$\left\{H_f^n\left(N_{\alpha_r}, N_{\tilde{\alpha}_r}; H\right), \pi_{\alpha_r'}^{\alpha_r *} \| \alpha_r, \alpha_r' \in, Cov^r\left(X\right)\right\}.$$

Let denote their limiting groups as

$$H_n^{inf}\left(X, A; G\right) \text{ and } H_f^n\left(X, A; H\right)$$

and name them as $n-$dimensional spectral homological and cohomological Chogoshvili groups of second family of the pair $\left(X, A\right) \in LP_2$ over the groups of coefficients G and H, based on infinite chains and finite cochains respectively.

It has been proved that H_*^{inf} is a semi-exact homology theory, while H_f^* satisfies all the Eilenberg-Steenrod axioms for cohomology theory. If $\left(X, A\right) \in LP_2$, the group G is compact and $G \big| H$, then the above constructed homology and cohomology groups are dual, i.e.

$$H_n^{inf}\left(X, A; G\right) \Big| H_f^n\left(X, A; H\right),\ n \in Z.$$

References

1. Eilenberg S., Steenrod N. Foundations for of Algebraic topology. – Princeton University Press, 1952.
2. Chogoshvili G. Trudy Tbilisskogo Matematicheskogo instituta AN GSSR. T.18, 1951.
3. Mdzinarishvili L. Trudy Tbilisskogo Matematicheskogo instituta AN GSSR. T.59, 1978.
4. Massey W. Homology and Cohomology Theory. – New York and Basel, 1978.
5. Baladze D. Issledovania po Theory Homology (ekctraordinarnie theory). – Tbilisi, 1984.

ON SOME STEFFENSEN METHOD MODIFICATIONS FOR SOLVING NON-LINEAR EQUATIONS

M.Y. Bartish, O.V. Kovalchuk, N.P. Ohorodnyk
Ivan Franko National University of Lviv, Ukraine
mykhailo.bartish@gmail.com, olyak2005@gmail.com, ogorodnyk.nataly@gmail.com

Let's consider the problem

$$P(x) = 0 \text{ where } P: R^n \to R^m \quad (1)$$

There are some number of algorithms for solving problem (1). We proposed new approach for building methods that could help us to solve problem (1). The new algorithm achieves a solution with fewer calculations than basis and has next view

$$u_k = \Phi(x_k);$$
$$x_{k+1} = x_k - P(x_k, u_k)^{-1} P(x_k). \quad (2)$$

Theorem. Let's next conditions are satisfied.

1. Φ(x) operator that satisfies condition $\|\Phi(x) - x_*\| \le C\|x_k - x_*\|^\tau$, where C$> 0$, $\tau \ge 1$, x_* - solution of the problem (1).
2. For $x, y \in X$,

$X = \{x \in R^n: \|F(x)\| \le \|F(x_0)\|\}: \|P(x,y)^{-1}\| \le B$,
where $B > 0$.

3. For $x, y, z \in X$:

$$\|F(x,y) - F(x,z)\| \le M\|y - z\|, \text{ where } M > 0.$$

4. The initial approximation x_0 is chosen to satisfy the condition

$$q^\tau = BMC\|x_0 - x_*\|^\tau < 1.$$

Then the sequence x_k is defined correctly and next evaluation can take place

$$\|x_k - x_*\| \le q^{(1+\tau)^k - 1}\|x_0 - x_*\|.$$

We propose to consider some cases of choosing operator Φ(x)

$$\Phi(x_k) = x_k - P(x_{k-1}, u_{k-1})^{-1} P(x_k)$$

or

$$\Phi(x_k) = x_k - P(x_k, x_k - \gamma P(x_k))^{-1} P(x_k).$$

CONDITIONS OF SOLVABILITY OF NONLINEAR BOUNDARYVALUE PROBLEMS UNSOLVED WITH RESPECT TO THE DERIVATIVE

P. Benner[1], S. Chuiko[2], O. Nesmelova[3]
[1]Max Planck Institute for Dynamics of Complex Technical Systems, Germany
[2]Donbass State Pedagogical University, Ukraine
[3]Institute of Applied Mathematics and Mechanics of the NAS of Ukraine
benner@mpi-magdeburg.mpg.de, chujko-slav@ukr.net, star-o@ukr.net

We have found constructive necessary and sufficient conditions for solvability and a scheme for constructing solutions for a nonlinear boundary-value problem unsolved with respect to the derivative. On the basis of the Adomian decomposition method, convergent iterative schemes computing approximations to solutions of a nonlinear boundary-value problem unsolved with respect to the derivative are constructed. The relevance of studying the nonlinear boundary-value problem, unsolved with respect to the derivative, is related to the fact that the study of the traditional problem, which is solved with respect to the derivative, is sometimes complicated, for example, in the case of nonlinearities that are not integrable in elementary functions. In addition, the construction of solutions of nonlinear boundary-value problems, for example, with using the method of simple iterations is significantly complicated by the calculation of derivative nonlinearities. We achieve the acceleration of the convergence of iterative schemes by calculating the derivatives of nonlinearities at each step. Given the above, we have simplified the computation of derivatives of nonlinearities and the possibility of finding solutions of nonlinear boundary-value problems, in particular periodic boundary-value problems, in elementary functions using the Adomian decomposition method. In this case, the use of the Adomian decomposition method significantly simplified the proof of convergence of iteration schemes for constructing solutions of nonlinear boundary-value problems.

As examples of the application of the constructed iterative scheme, approximations to the solutions of a periodic boundary-value problem for a Rayleigh-type equation unsolved with respect to the derivative are found, including the case of a periodic problem for the equation that determines the motion of a satellite in an elliptical orbit.

OPTIMIZATION PROBLEMS IN GAME PROCESSES

I.V. Beyko
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnical Institute", Ukraine
ivan.beyko@gmail.com

We consider the optimization tasks of controlled processes

$$\dot{x}_i(t) = f_i\left(x(t), y(t), u(t)\right), \quad i = 1, \ldots, n_x,$$

$$\dot{y}_i(t) = g_i\left(x(t), y(t), v(t)\right), \quad i = 1, \ldots, n_y,$$

$$\dot{z}(t) = g\left(z(t), q(t), w(t)\right),$$

with incomplete data for parameters $q \in Q(t)$ and for random variables $w(t) \in W(t)$. Optimal controls $u(t) \in U(t)$, $v(t) \in V(t)$ are defined as solutions of optimization problems with optimality criteria determined by mathematical expectations

$$\max_{u(t)\in U(t)} \min_{v(t)\in V(t)} M_w F(x(T_m)), \quad \max_{u(t)\in U(t)} M_w \min_{\substack{v(t)\in V(t) \\ q\in Q}} F(x(T_m)).$$

Random moments $t = T_m$ of time occurrence of the event $(z(T_m) \in Z_1) \cup (z(T_m) \in Z_2)$ are calculated according to the given initial state $(x(t_0), y(t_0), z(t_0))$

$$s1 = \arg \min_{i=1,\ldots,n_y} \rho(x_i(t), z(t)),$$

$$s2 = \arg \min_{i=1,\ldots,n_y} \rho(y_i(t), z(t)),$$

$$\rho_1 = \rho\left(x_{s1}(t), z(t)\right); \ \rho_2 = \rho\left(y_{s2}(t), z(t)\right); \ \rho_3 = \min\left\{\rho_1, \rho_2\right\};$$

if $\rho_3 \le d_1$ then if $\rho_1 \le \rho_2$

then $z(t_{k+0}) = h_{s1}(x(t_k), y(t_k), u_{s1}(t_k), q_{s1}, w(t_k))$

else $z(t_{k+0}) = h_{s2}(x(t_k), y(t_k), v_{s2}(t_k), q_{s2}, v(t_k), w(t_k))$.

The cases of constructing optimal controls according to the criteria of maximizing the probabilities $P(z(T_m) \in Z_1)$ of the occurrence of the event $z(t) \in Z_1$ or minimizing the probabilities $P(z(T_m) \in Z_2)$ of the occurrence of the event $z(T_m) \in Z_2$ or maximizing the value

$$M_w F(x(T_m)) = P\left(z(t) \in Z_1\right) - P\left(z(t) \in Z_2\right)$$

are considered. Such controls are built using the methods of stochastic gradients. Possibilities of their practical implementation have been found.

OPTIMIZATION PROBLEMS IN MODERN MACHINE LEARNING

I.V. Beyko, **O.V. Kuzma**
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnical Institute", Ukraine
ivan.beyko@gmail.com

We consider tasks of models of controlled systems optimization simultaneously with management decisions optimization. To solve generalized problems of complex systems optimization with incomplete data, we build adequate mathematical and computer models using algorithms of the constructive theory of optimal control, algorithms for building optimal models in conditions of incomplete data, as well as algorithms of a posteriori optimization with the search for "useful" information for identification of possible critical subsystems that require priority improvement. To find the necessary "useful" information, we build "utility functions" or their asymptotic or minimax approximations [1-2]. Available information about cause-and-effect dependencies in interacting subsystems is reduced to a unified model with deterministic and/or stochastic subsystems of functional algebra-integrato-differential equations with partial derivatives [1-2].

Automation of subsystems with neural networks optimization is carried out using ML-algorithms. Currently, there are already effective ML/AI products and libraries, in particular, TensorFlow, PyTorch (-implemented on Python open software tools). Particularly effective are the modern OpenAI, Wolfram Cloud - including even creating plugins for ChatGPT that may call Wolfram Language and/or Wolfram|Alpha. Within Wolfram Language it is possible to call ChatGPT. As well in ChatGPT it is possible just tell to include a piece of his initial Wolfram Language code (and talk in ChatGPT about the functions or other things defined in that code).

References

1. Beyko I.V. Extreme models of complex systems and the method of decomposition in computational experiments // Vesn. Kyiv.Univ. Modeling and optimization of complex systems. – 1982. – Issue 1. – P. 72-81.

2. Beyko I.V., Furtel O.V., Spivak Ju.V. Generalized Solutions of Optimal Control Problems // System Research & Information Technologies. – 2020. – Vol. 4. – P. 103-113.

TO THE CONSTRUCTION OF GENERALIZED OPTIMAL PHASE TRAJECTORIES

I.V. Beyko, **Yu.V. Spivak**
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnical Institute", Ukraine
ivan.beyko@gmail.com

We consider methods for constructing minimizers $\bar{u} = (x, u, t_0, T)$ of the functional $F_0(\bar{u})$ under restrictions $F_i(\bar{u}) \le 0,\ i = \overline{0,m}$,

$$F_i(\bar{u}) \triangleq \int_{t_0}^{T} h_i(x(t), u(t), t)dt + g_i(t_0, T, x(t_0), x(T)) \le 0\ ,\ i = \overline{0,m}$$

$$\dot{x}(t) = f(x(t), u(t), t),\ \ t \in [t_0, T].$$

If the functions f, h_i are continuous together with their derivatives at and the functions g_i, $i = \overline{0,m}$ are continuously differentiable, then the value $u^0(t)$ (at the optimal solution $\bar{u}^0 = (x^0, u^0, t_0^0, T^0)$) is constructed as the maximizer

$$u^0(t) = \arg\max_{u \in \Omega}(\psi^0(t),\ f(x^0(t), u, t)) - \sum_{i=0}^{m} \lambda_i^0 h_i(x^0(t), u, t))$$

of the Hamiltonian of the generalized π-system with the adjoint system

$$\frac{d\psi^0(t)}{dt} = -\psi^0(t) f_x'(x^0(t), u^0(t), t) + \sum_{i=0}^{m} \lambda_i h_{ix}'(x^0(t), u^0(t), t)\ ,$$

$$\psi^0(t_0^0) = \sum_{i=0}^{m} \lambda_i^0 g'_{x(t_0)}(t_0, T, x^0(t_0), x^0(T))\ ,$$

$$\psi^0(T^0) = -\sum_{i=0}^{m} \lambda_i^0 g'_{x(T)}(t_0, T, x^0(t_0), x^0(T))\ .$$

If the set $\left\{ f\left(x(t), u, q(t)\right) \mid u \in \Omega \right\}$ is nonconvex, then the $u^0(t)$ may not exist, but there are generalized solutions $\tilde{x}^0$ in the phase space of admissible trajectories $\dot{\tilde{x}}(t) = co\ f\left(\tilde{x}(t), \Omega, q(t)\right)$, which are constructed using decomposition algorithms.

GROUP DECISION-MAKING BASED ON THE AGGREGATED ANALYTIC HIERARCHY PROCESS

O. Bezuevska[1], O. Kapustian[1], S. Bekesiene[2]
[1]Taras Shevchenko National University of Kyiv, Ukraine
[2]General Jonas Zemaitis Military Academy of Lithuania
bezuievska@knu.ua, olena.kap@gmail.com,
svajone.bekesiene@lka.lt

In this paper we investigate the application of the aggregated analytic hierarchy process (AHP) for group decision-making based on a survey of military personnel regarding factors that help them overcome stress.

In order to solve the given task, we investigate various methods of aggregation of judgments, which allow combining individual preferences into group consensus, and also study approaches to calculating average values for pairwise comparisons, which contribute to achieving a more democratic decision-making process and prevent the dominance of individual group members. Also, the work implements the aggregated analytic hierarchy process in the Python programming language in order to evaluate the factors that most help military personnel in the fight against stress.

References

1. Saaty T. L. Fundamentals of decision making and prority theory with the analytic hierarchy process. – Pittsburgh, PA: RWS Publications, 1994. – 527 p.
2. Aruldoss M., Lakshmi T. M., Venkatesan V. P. A Survey on Multi Criteria Decision Making Methods and Its Applications. // American Journal of Information Systems. – 2013. – Vol. 1 (1). – P. 31–43.
3. Ossadnik W., Schinke S., Kaspar R.H. Group Aggregation Techniques for Analytic Hierarchy Process and Analytic Network Process: A Comparative Analysis. // Group Decision and Negotiation. – 2015. – Vol. 25 (2). – P. 421–457. URL: https://doi.org/10.1007/s10726-015-9448-4

INVERSE PROBLEMS FOR NONLINEAR BOUNDARY-VALUE PROBLEMS WITH DELAY

O. Boichuk[1], S. Chuiko[2], V. Chuiko[3]
[1]Institute of Mathematics of NAS Ukraine, Ukraine
[2]Donbass State Pedagogical University, Ukraine
[3]Taras Shevchenko National University of Kyiv, Ukraine
boichuk@imath.kiev.ua, chujko-slav@ukr.net, vitya.chuyko@gmail.com

We investigate a weakly nonlinear boundary-value problem for a system of differential equations with delay. The initial function of the differential system with delay contains an unknown eigenfunction that provides the solvability of the weakly nonlinear boundary-value problem. By employing the Adomian decomposition method, we derive conditions for solvability and develop a new iterative scheme to find solutions of the weakly nonlinear boundary-value problem for a system of differential equations with delay as well as its eigenfunction [1]. The urgency of the study of the boundary-value problem (1) is connected with wide application of similar problems in the study of nonisothermal chemical reactions. Examples of simulation of these reactions are given in [2, 3]. In the construction of solutions of nonlinear boundary-value problems, there appears the problem of impossibility of determination of solutions in terms of elementary functions which, in turn, leads to great errors of solutions of nonlinear boundary value problems. In [3], the acceleration of convergence of iterative schemes is realized by calculation of derivatives of nonlinearities at each step.

References

1. Boichuk O., Chuiko S., Chuiko V. Adomian decomposition method in the theory of inverse problems for nonlinear boundary-value problem with delay// Journal of Mathematical Sciences. – 2024. – Vol. 211. – P. 111 – 123.
2. Benner P., Seidel-Morgenstern A., Zuyev A. Periodic switching strategies for an isoperimetric control problem with application to nonlinear chemical reactions // Applied Mathematical Modelling. – 2019. – Vol. 69. – P. 287 – 300.
3. Chuiko S.M., Chuiko O.S., Popov M.V. Adomian decomposition method in the theory of nonlinear boundary-value problems // J. Math. Sci. – 2023. – Vol. 277. – P. 338 – 351.

FORECASTING METHODS BASED ON POLYNOMIAL EXTRAPOLATION SET ANALYSIS

A.Ya. Bomba[1], Y.V. Turbal[1], M.Y. Turbal[1], D.A.Smirnov[1], B.Y.Turbal[2]

[1]National University of Water and Environmental Engineering, Ukraine

[2]Taras Shevchenko National University of Kyiv, Ukraine

abomba@ukr.net, turbaly@gmail.com

In this paper we consider the problem of time series forecasting. Many forecasting methods are known [1], but the problem is still relevant. We propose a concept of forecasting, which is based on the construction of a special set of all possible polynomial extrapolation values (polinomial extrapolation set). Then we do not use the input time series directly, but perform an analysis of the polinomial extrapolation set.

The polynomial extrapolation set can be defined as follows:

$$S^m(f_n, f_{n-1},..., f_{n-m+1}) = \{P^0((n+1)\Delta), P^1((n+1)\Delta),..., P^{m-1}((n+1)\Delta)\}, \quad (1)$$

where

$$P_2^{m-1}((n+1)\Delta) = \sum_{k=1}^{m}(-1)^{k-1}C_m^k f_{n-k+1}, \quad (2)$$

$f_i = f(i\Delta), i = n, n-1,..., n-m$ are the known values of some function at the points $i\Delta$ respectively, C_m^k-binomial coefficients.

We can consider set (1) as a sequence of increasing degrees of polynomials. Then the optimal polynomial prediction can be constructed in the case where the sequence coincides. Let the sequence monotonically increase or decrease, while the distance between adjacent points monotonically decreases. Then the optimal degree of the polynomial for forecasting is maximal. Let the sequence be non-monotonic, that is, it has points of local extrema. If the intervals between adjacent maxima-minima form a nested sequence - each subsequent one is nested in the previous one, then we can claim that there is convergence to some constant. We find the constant as the middle of the interval of change of convexity.

References

1. Turbal Y., Shlikhta G., Turbal M., Turbal B. The polynomial forecasts improvement based on the algorithm of optimal polynomial degree selecting.// Eastern-European Journal of Enterprise Technologies. – 2023. – Vol. 5/4(125). – P. 34–42.

OPTIMAL TWO-THRESHOLD STRATEGY FOR A FINITE RETRIAL QUEUE

M. Bratiichuk[1], I. Usar[2]
[1]Silesian University of Technology, Poland
[2]Taras Shevchenko National University of Kyiv, Ukraine
[1]Mykola.Bratiichuk@polsl.pl, [2]usar69@ukr.net

We are dealing with a retrial queue of *M/M/*1*/* type (see detailed description in [1]). It is supposed the number of places on the orbit to be equal to $m < \infty$. The input flow of the primary calls follows the Poisson process with intensity λ, ν is a parameter of the repeated calls, and $\xi(t)$ stands for the number of calls on the orbit at time t.

The service rate follows the so-called *two-threshold* strategy (see [2]): if $\xi(t) \le a < m$, then the service rate is μ_1 and the service rate is μ_2, if $\xi(t) \ge a + 1$.

We also define the process $\eta(t)$ as follows: $\eta(t) = 0$ if at the moment t the server is free, $\eta(t) = 1$ or 2 if at that moment the server works with the service rate μ_1 or μ_2 respectively.

Let

$$\pi_{ki} = \lim_{t\to\infty} P\{\eta(t) = k, \xi(t) = i / \eta(0) = l, \xi(0) = j\}, \ k = 0,1,2.$$

We put

$$\chi = -\lambda / \nu, \ \beta = \lambda / (\lambda + \mu_1), \ C_{kj} = \left(\frac{\lambda}{\mu_k}\right)^j \prod_{l=1}^{j-1}\left(1 + \frac{\lambda}{l\nu}\right), \ k = 1,2.$$

Theorem 1.

$$\frac{\pi_{oj}}{\pi_{00}} = \begin{cases} \dfrac{\lambda C_{1j}}{j\nu}, & 1 \le j \le a, \\ \dfrac{\lambda C_{1a}\pi_{00}}{k\nu}\left[\beta^{k-a} + \dfrac{\lambda C_{2k}}{\mu_2\nu}\displaystyle\sum_{l=a}^{k-1}\frac{l\nu + \lambda + \mu_1}{lC_{2l}}\right], & a+1 \le j \le m. \end{cases}$$

$$\frac{\pi_{1j}}{\pi_{00}} = \begin{cases} C_{1j+1}, & 0 \le j \le a-1, \\ \beta^{j-a+1}C_{1a}, & a \le j \le m-1, \\ \beta^{m-a}\dfrac{\lambda}{\mu_1}C_{1a}, & j = m. \end{cases}$$

$$\frac{\pi_{2j}}{\pi_{00}}=\begin{cases}\dfrac{\lambda C_{1a}C_{2j+1}}{\mu_2}\displaystyle\sum_{l=a}^{j}\left(1+\frac{\lambda+\mu_1}{l\nu}\right)\frac{\beta^{a-l-1}}{C_{2l+1}}, & a\le j\le m-1,\\ \dfrac{\lambda^2 C_{1a}}{m\nu\mu_2^2}\left[(\lambda+m\nu)C_{2m}\displaystyle\sum_{l=a}^{m-1}\left(1+\frac{\lambda+\mu_1}{l\nu}\right)\frac{\beta^{a-l-1}}{C_{2l+1}}+\beta^{m-a}\right], & j=m.\end{cases}$$

Using these formulae, we considered the optimization problem when the service rate is submitted to the two-threshold strategy.

References

1. Artalejo J.R., Gomes-Corral A. Retrial Queueing Systems. – Computational Approach, Springer Verlag, 2008.

2. Xuelu Z., Jinting W., Qing M. Optimal Design for a Retrial Queueing System with State Dependent Service rate. // Journal of Systems Science and Complexity. – 2017. – Vol. 30. – P. 883-900.

BIOMETRIC IDENTIFICATION IN CONDITIONS OF UNCERTAINTY OF THE POSSIBILITY OF IDENTIFICATION

O. Bychkov, K. Merkulova, B. Pavliukh

Taras Shevchenko National University of Kyiv, Ukraine,

oleksiibychkov@knu.ua, k.merkulova@knu.ua, bohdanpavliukh@knu.ua

The report contains an analysis of biometric identification using image embeddings [1]. For the task of comparing image embeddings, an experimental study of 3 methods of finding the distance between vectors was carried out: Euclidean, Manhattan and cosine distance. Different methods give different relative difference between the distance for vectors corresponding to images of the same person and for vectors corresponding to images of different people. We consider the method that will give the largest such difference to be optimal. The analysis of the obtained distance results showed that the difference in the distance between the vector representations of one person and different people stands out, which indicates the possibility of using all the investigated methods of person identification, however, for the Manhattan distance, this difference is less noticeable (which was generally expected, based on its formula), for the Euclidean distance, the difference is more noticeable, but using the cosine distance, the best result is definitely obtained (the difference is the largest). Therefore, it is optimal to use the cosine distance, because this method best distinguishes the faces of different people. Empirically, a threshold value was found, the purpose of which is

to provide information about the possibility of identifying a person. That is, if the smallest of the found distances between the obtained vector representation and the stored vector representations is less than this threshold value, then we consider that there is no information about the person and his identification is impossible.

References

1. Merkulova K., Pavliukh B. Use of Convolutional Neural Networks for Identifying Additional Features on a Digital Image of Human Face. – Proceedings of the "Dynamical System Modelling and Stability Investigation" (DSMSI-2023) Conference, CEUR Workshop Proceedings, Kyiv, Ukraine, December 19-21, 2023. – P. 193-203.

DECISION MAKING IN OBJECT DETECTION ON UAV IMAGERY

O. Bychkov, K. Merkulova, A. Poliovyi
Taras Shevchenko National University of Kyiv, Ukraine
oleksiibychkov@knu.ua, k.merkulova@knu.ua, arseniipolioviy@knu.ua

In this study, we address the challenge of object detection on UAV imagery, focusing on decision-making amidst uncertainties inherent in aerial surveillance. The development of a robust object detection system for UAVs is crucial for various applications such as traffic monitoring, disaster management, and military reconnaissance. Leveraging the YOLO (You Only Look Once) model [1], the approach emphasizes high-speed processing and accuracy in diverse environmental conditions. The methodology involves a comprehensive data preparation phase, where UAV-captured images are annotated and preprocessed to enhance the model's learning capability. The object detection model is trained using a dataset that includes a variety of traffic scenarios to ensure generalizability and robustness. Post-processing techniques, including image segmentation and edge detection (e.g., Sobel and Kirsche filters) [2], are applied to refine detection results and mitigate false positives. The scientific novelty of the work lies in the integration of segmentation techniques to improve detection accuracy and the systematic evaluation of model performance under different lighting and weather conditions. The system's performance is assessed based on metrics such as precision, recall, and F1-score.

References
1. Lakshmanan V. Practical Machine Learning for Computer Vision: End-To-End Machine Learning for Images. – O'Reilly Media, 2021. – 480 p.
2. Gonzalez R.C., Woods R.E. Digital Image Processing (4th ed.) – Pearson India, 2019. – 216 p.

THE CONTROL PROBLEM FOR A DIFFUSION MODEL OF EPIDEMIC WITH SEMIMARKOV SWITCHING

Ya. M. Chabaniuk[1,2], U. T. Khimka[2], A. A. Lytvyn[2]
[1]Lublin University of Technology, Poland
[2]Ivan Franko National University of Lviv, Ukraine
Yaroslav.chab@gmail.com

Consider the control problem for a diffusion model of epidemic [1]:

$$a'(t) = \mu(x) + \gamma(x) + m(t) + \beta(x)a(t) + \sigma_1(u(t))w_1(t),$$

$$m'(t) = \beta(x)a(t) - \beta(x)a^2(t) - m(t) + \sigma_2(u(t))w_2(t).$$

Here $u(t)$ – control process; x – semimarkov switching process; and the koefficient μ, γ, β – characteristic for the epidemic process, w_1, w_2 – Wiener process [2].

The optimality of treatment costs is characterized by functionality:

$$G(a(t), m(t), u(t)) \to \min. \qquad (1)$$

The value of the control $u(t)$ is determined using a stochastic optimisation procedure for (1) [2].

$$\frac{du}{dt} = \alpha(t)\nabla_{b(t)}G(a(t), m(t), u(t)),$$

where $$\nabla_{b(t)}G(\cdot,\cdot,u) = \frac{G(\cdot,\cdot,u+b(t)) - G(\cdot,\cdot,u-b(t))}{2b(t)}. \qquad (2)$$

If following conditions are satisfied

$$\int_0^\infty \alpha(t)dt = \infty, \quad \int_0^\infty \alpha^2(t)dt < \infty, \quad \int_0^\infty \alpha(t)\beta(t)dt < \infty,$$

the procedure (2) converges to the point of reaching the minimum criterion (1).

References
1. Santonja F., Shaikhet L. Analysing social epidemics by delayed stochastic models. // Discrete Dynamics in Nature and Sosiety. – 2012. – Article ID 530472.

2. Chabanyuk Y., Nikitin A., Khimka U. Asymptotic Analyses for Complex Evolutionary Systems with Markov and Semi-Markov Switching Using Approximation Schemes // Mathematics and Statistics. – John Wiley & Sons, October 2, 2020. – 240 p.

ASYMPTOTIC PROPERTIES OF THE STOCHASTIC EVOLUTION UNDER MARKOV-MODULATED POISSON PERTURBATIONS

Ya. M. Chabanyuk[1], U. T. Khimka[1], S. A. Semenyuk[2]
[1]Ivan Franko National University of Lviv, Ukraine
[2]Lviv National Polytechnic University, Ukraine
yaroslav.chabanyuk@lnu.edu.ua, ulyana.khimka@lnu.edu.ua
semenyuk@gmail.com

Let's consider a stochastic evolution process perturbed by the Markov-modulated Poisson process (MMPP):

$$du^{\varepsilon}(t) = C(u^{\varepsilon}(t)) + N(t), \quad u^{\varepsilon}(t) \in R$$

The Poisson process $N(t), t \geq 0$ is a counting process for the number of events that have occurred up to time t. The arrival rate of events at time t is given by $\lambda\big(x(t)\big)$ i.e., rate parameter is modulated by the state Markov process.

Here the process $x(t), t \geq 0$ is uniformly ergodic Markov process in the standard phase space $(X, \boldsymbol{X})$ with stationary distribution $\pi(B)$ and infinitesimal operator (generator) $\mathrm{Q}\varphi(\mathrm{x}) = \mathrm{q}(\mathrm{x}) \int_X \mathrm{P}(\mathrm{x}, \mathrm{dy})[\varphi(\mathrm{y}) - \varphi(\mathrm{x})], \varphi \in B(X)$ [1].

Such models are commonly used in network traffic modeling, maintenance and reliability, financial modeling, and epidemiology.

Asymptotic properties of the stochastic evolution have been investigated in this work. To achieve these asymptotic properties of the MMPP itself [2] has been used.

References

1. Chabanyuk Y., Nikitin A., Khimka U. Asymptotic Analyses for Complex Evolutionary Systems with Markov and Semi-Markov Switching Using Approximation Schemes // Mathematics and Statistics. – John Wiley & Sons, October 2, 2020. – 240 p.

2. Semenyuk S. Asymptotic properties of the Markov-modulated Poisson process // Proceedings of the XXXVIII International Conference Problems of decision making under uncertainties (PDMU-2023) – 2023 – P.93

CONTROL PROBLEM GENERATOR FOR A DIFFUSION PROCESS IN A LÉVY SCHEME WITHIN A SEMI-MARKOV ENVIRONMENT

Ya. M. Chabanyuk[1], A. V. Nikitin[2], R. A. Chypurko[1]
[1]Ivan Franko National University of Lviv, Ukraine
[2]National University "Ostroh Academy", Ukraine
yaroslav.chabanyuk@lnu.edu.ua, chypurko.roman@gmail.com
anatolii.nikitin@oa.edu.ua

Let's consider a control problem for a random transport process $y(t) \in R^d$ with control $u(t) \in (X, \boldsymbol{X})$ [1]. The transport process is defined by the equation:

$$dy(t) = C(y(t), x(t), u(t))dt + d\eta(t, u(t)), \quad (1)$$

where $\eta(t,u), t \geq 0$, is an impulse disturbance process, which in the Lévy approximation scheme is defined by the relation [1]

$$\eta(t, u(t)) = \int_0^t \eta(ds, x(s), u(s)ds. \quad (2)$$

Let the quality criterion of control $u(t)$ for the transport (1) be defined by the function $G(y,x,u)$ with a unique point u^* where $G(y,x,u^*) = \min G(y,x,u)$.

Thus, for the control $u(t)$ let us consider the stochastic optimization procedure [1]

$$\frac{\alpha t}{dt} = d(t)\nabla_{\beta(t)} G(y,x,u), \quad (3)$$

where $\nabla_{\beta(t)} G(y,x,u) = \dfrac{\left(G(y,x,u+\beta(t)) - G(y,x,u-\beta(t))\right)}{2\beta(t)}$.

For problems (1), (2), and (3), a generator in the small parameter scheme has been constructed.

References

1. Chabanyuk Y. Asymptotic Analyses for Complex Evolutionary Systems with Markov and Semi-Markov Switching Using Approximation Schemes/ Chabanyuk Y., Nikitin A., Khimka U.// Mathematics and Statistics. – John Wiley & Sons, October 2, 2020. – 240P.

CONVERGENCE OF THE PROCEDURE OF STOCHASTIC APPROXIMATION OF THE SHAIKHET–SANTONJIA MODEL WITH SEMI-MARKOV SWITCHES

Ya. M. Chabanyuk[1], O. B. Stepaniak[2]
[1] Lublin University of Technology, Poland.
[2]Ivan Franko National University of Lviv, Ukraine
y.chabanyuk@pollub.pl, oleh.stepaniak@lnu.edu.ua

In the presented material, the procedure of stochastic approximation (PSA) is constructed

$$\begin{cases} \alpha'(t) = c(t)\left[\mu_\xi + \gamma_\eta m(t) + \beta_\zeta Q^2(t) - Q(t)(\mu_\xi + \gamma_\eta + \beta_\zeta) + \sigma_1 w_1 \right] \\ m' = c(t)\left[\beta_\zeta a(t) - \beta_\zeta a^2(t) - m(t)(\alpha + \mu_\xi) + \sigma_2 w_2 \right] \end{cases} \quad (1)$$

for the pattern of alcohol consumption in Spain [1].

Here, the coefficient μ_ξ, γ_η, β_ζ take constant values at time intervals with uniform and normal distributions. The control function $c(t)$ satisfies the necessary conditions of PSA:

$$\begin{cases} \int_{t_0}^{\infty} c(t)\,dt = \infty, \\ \int_{t_0}^{\infty} c^2(t)\,dt < \infty. \end{cases}$$

Vector (w_1, w_2) – two-dimensional Wiener process.

Note that the nature of changes in the specified coefficients indicates semi-Markov switching of the model [2].

The implementation of PSA (1) indicates convergence to the equilibrium point of the original model, which is obtained from similar calculations from the model [1].

References

1. Santonjia F., Shaikhet L. Analysing Social Epidemic by Delayed Stochastic Models. // Discrete Dynamics in Nature and Society. – 2012. – Article id 530472. – 13 p.
2. Chabanyuk Y., Nikitin A., Khimka U. Asymptotic Analysis for Complex Evolutionary System with Markov and Semi-Markov Using Approximation Schemes. – John Wiley & Sons, 2020. – 240 p.

MACHINE LEARNING MODELS FOR DECISION-MAKING UNDER UNCERTAINTY: TRACKING SANCTION VIOLATIONS AMIDST THE RUSSIAN INVASION OF UKRAINE

I.R. Cheherst
SkyPulse LLC, Kyiv, Ukraine
chegerst.i@gmail.com

The work aims to understand how advanced mathematical frameworks and machine learning algorithms can aid in identifying and mitigating sanction violations, thereby enhancing compliance and enforcement mechanisms

The model for identifying anomalies in high-dimensional data, such as SEC filings or blockchain transactions, by modeling the density of the data and identifying points that fall in low-density regions, which is based on Gaussian Mixture Model (GMM) as a probabilistic model that assumes all the data points are generated from a mixture of several Gaussian distributions with unknown parameters.

References

1. Xin, L., Xin, K., & Xin, H. Machine learning for decision-making under uncertainty. – University of Science and Technology of China, 2021. - hxin@ustc.edu.cn
2. C. Steele, G. Schreurs, Weng, Y.N., J. Boscolo Cappon. Sanctions Screening: Challenges and Control Considerations – Global Investigations Review, 2023, - csteele@forensicrisk.com

GUARANTEED LINEAR MEAN SQUARE ESTIMATES OF THE AVERAGE VALUE OF RANDOM PROCESSES

L. Chukhrai[1], O. Nakonechnyi[2], V. Chukhrai[1], M. Loseva[2]
[1]Lviv National Environmental University, Ukraine
[2]Taras Shevchenko National University of Kyiv, Ukraine
a.nakonechniy@gmail.com

Let us observe on the interval $(0,T)$ the implementation of a scalar random process $\xi(t)$ with an unknown mean and an unknown correlation function. We are looking for an estimate of the average value $E\xi(t)=\varphi(t)$ in the form

$$\hat{\varphi}(t)=\int_0^T u(t,s)\xi(s)ds+c(s),$$

where $u(t,s)$, $c(s)$ are some functions integrated with the square.

We study cases when $\varphi(t)$ has the form $\varphi(t)=\sum_{k=1}^{m}\theta_k g_k(t)$, where the functions $g_k(t)$ are known, or when the function $\varphi(t)$ is differentiated.

We assume that the unknown mean values and the correlation function belong to sets of functions integrated with the square G_1 and G_2.

The guaranteed estimations of functions $\hat{u}(t,s)$ and $\hat{c}(s)$ we found from the condition $(\hat{u}(t,s),\hat{c}(s))\in Arg\min\sigma(u,c)$, where

$$\sigma^2(u,c)=\sup_{G_1,G_2}E\int_0^T(\varphi(t)-\hat{\varphi}(t))^2dt.$$

We found the errors of the linear estimates as well as expressions for the approximate linear guaranteed estimates in case when the sets G_1 and G_2 has the form

$$G_1=\left\{\varphi:\int_0^T(\varphi^{(k)}(t))^2dt\le q^2\right\},$$

$$G_2=\left\{R:\int_0^T\int_0^T(R(t,s)-R_0(t,s))^2dtds\le q_2^2\right\},$$

where $\varphi^{(k)}(k)$ are k-order derivative of the function $\varphi(t)$, $R(t,s)$ is correlation function of the process $\xi(t)$ and $R_0(t,s)$ is known correlation function. We show that such estimates in some cases coincide with guaranteed estimates.

PARTIAL MOMENT EQUATIONS FOR LINEAR DIFFERENTIAL EQUATIONS WITH RANDOM COEFFICIENTS AND RANDOM JUMPS OF SOLUTIONS

S.V. Degtyar, Yu.V.Shusharin
Kyiv National Economic University named after Vadym Hetman, Ukraine
shusharin@meta.ua

A system of linear differential equations is considered, the coefficients of which depend on a random finite-valued Markov process $\xi(t)$.

$$\frac{dX(t)}{dt}=A(t,\xi(t))X(t). \qquad (1)$$

Let the random process $\xi(t)$ takes on values $\theta_1,...,\theta_q$ with probabilities

$$p_k(t) = \mathrm{P}\{\xi(t) = \theta_k\},\ \ (k = 1,...,q)\,, \tag{2}$$

satisfying the system of linear differential equations

$$\frac{dp_k(t)}{dt} = \sum_{s=1}^{q} a_{ks}(t)\, p_s(t)\,. \tag{3}$$

$$a_{kk}(t) \le 0,\ \ a_{ks}(t) \ge 0 \quad (k \ne s)\,,\ \ \sum_{s=1}^{q} a_{ks}(t) \equiv 0\,,\ \ (k,s = 1,...,q)\,. \tag{4}$$

Let a random process $\xi(t)$ change its value abruptly at moments

$$t_j \quad (j = 0,1,2,...);\ t_0 = 0 < t_1 < t_2 < ...$$

We assume that simultaneously with the process $\xi(t)$, the phase vector $X(t)$ also abruptly changes its value according to the formulas

$$X(t_j + 0) = C_{ks}(t_j)X(t_j - 0) \quad (k,s = 1,...,q)\,, \tag{5}$$

If $\quad \xi(t_j - 0) = \theta_s,\ \ \xi(t_j + 0) = \theta_k \quad (k \ne s)\,.$

These equations were considered in [1].

Let us move from the system of differential equations (1), (3) to the system of linear difference equations, assuming $t_n = nh \quad (n = 0,1,2,...)$, $h > 0$.

The systems of differential equations (1), (3) are replaced by systems of difference equations of the form

$$X_{n+1} = X_n + hA(t_n, \xi_{n+1}, \xi_n)X_n,\ \ X_n \equiv X(t_n) \tag{6}$$

$$p_k(t_{n+1}) = p_k(t_n) + h\sum_{s=1}^{q} a_{ks}(t_n)p_s(t_n) \quad (k = 1,...,q)\,,\ (n = 0,1,2,...)\,.$$

Let's write down the system of equations

$$f_k(t_{n+1}, X) = (1 + ha_{kk}(t_n))\, f_k(t_n, (E + hA(t_n, \theta_k))X) \cdot$$

$$\cdot \left|\det(E + hA(t_n, \theta_k))^{-1}\right| +$$

$$+ \sum_{s=1, s\ne k}^{q} ha_{ks}(t_n)\, f_s(t_n, C_{ks}^{-1}(t_n)X) \cdot \left|\det C_{ks}^{-1}\right| \quad (k = 1...q) \tag{7}$$

Having expanded it in powers of the parameter *h*, we write

$$f_k(t_{n+1}, X) = f_k(t_n + h, X) = f_k(t_n, X) + \frac{\partial f_k(t_n, X)}{\partial t} h + ...$$

$$\det(E + hA(t_n, \theta_k))^{-1} = (\det(E - hA(t_n, \theta_k)) + \theta(h^2)) =$$

$$= 1 - hSpA(t_n, \theta_k) + 0(h^2);$$

$$f_k(t_n, (E + hA(t_n, \theta_k))^{-1} X) = f_k(t_n, X - hA(t_n, \theta_k) X) +$$

$$+0(h^2) = f_k(t_n, X) - \frac{Df_k(t_n, X)}{DX} hA(t_n, \theta_k) X + 0(h^2) \quad (k = 1...q)$$

Let's introduce the notation

$$t_n = t, \quad A_k(t) = A(t, \theta_k), \quad C_{kk}(t) = E \quad (k = 1...q).$$

In this case, we arrive at $h \to 0$ a system of linear functional equations for partial densities $f_k(t, X)$ $(k = 1...q)$

$$\frac{\partial f_k(t, X)}{\partial t} = -\frac{Df_k(t, X)}{DX} A_k(t) X - f_k(t, X) SpA_k(t) +$$

$$+\sum_{s=1}^{q} a_{ks}(t) f_s(t, C_{ks}^{-1}(t) X) \cdot \left|\det C_{ks}^{-1}(t)\right| \quad (k = 1, ..., q) \tag{8}$$

By *SpA* we denote the trace of a square matrix *A*

$$A = \left\| a_{ks} \right\|_1^m, \; SpA = \sum_{k=1}^{m} a_{kk} .$$

In this case, the system of equations (8) can be written as

$$\frac{\partial f_k(t, X)}{\partial t} = -div(f_k(t, X) A_k(t) X +$$

$$+\sum_{s=1}^{q} a_{ks}(t) f_s(t, C_{ks}^{-1}(t) X) \cdot \left|\det C_{ks}^{-1}(t)\right| \quad (k = 1, ..., q) \tag{9}$$

The probability density of a random solution *X(t)* of the system of equations (1) is determined by the distribution function

$$f(t, X) = \sum_{k=1}^{q} f_k(t, X), \tag{10}$$

where $f_k(t, X)$ $(k = 1, ..., q)$ solution of a system of partial differential equations (8).

Let us construct systems of linear differential equations that determine the mathematical expectation $M(t) = < X(t) >$ of a random solution and the matrix of partial moments of the second order $D(t) = < X(t) X^*(t) >$. Specific aspects were considered in the work [2].

Let $M(t) =< X(t) >= \int\limits_{E_m} Xf(t,X)dX = \sum\limits_{k=1}^{q} \int\limits_{E_m} Xf_{\,k}(t,X)dX$

$$M(t) = \sum_{k=1}^{q} M_k(t), \quad M_k(t) = \int\limits_{E_m} Xf_k(t,X)dX \quad (k = 1,...,q) \qquad (11)$$

After some transformations we obtain a system of vector equations

$$\frac{dM_k(t)}{dt} = A_k(t)M_k(t) + \sum_{s=1}^{q} a_{ks}(t)C_{ks}(t)M_s(t) \quad (k = 1,...,q) \qquad (12)$$

which determines the first moments of the random solution of the system of equations (1).

Let us derive a system of matrix equations for partial moments of the second order $D_k(t)$, $(k = 1,...,q)$. We have formulas

$$\begin{aligned} &D(t) =< X(t)X^*(t) >= \int\limits_{E_m} XX^* f(t,X)dX = \sum_{k=1}^{q} \int\limits_{E_m} XX^* f_k(t,X)dX; \\ &D(t) = \sum_{k=1}^{q} D_k(t), D_k(t) = \int\limits_{E_m} XX^* f_k(t,X)dX \quad (k = 1,...,q). \end{aligned} \qquad (13)$$

We multiply each equation (9) by the matrix XX^* and integrate over the entire space E_m. In this case, we obtain a system of matrix differential equations

$$\begin{aligned} &\frac{dD_k(t)}{dt} = A_k(t)D_k(t) + D_k(t)A_k^*(t) + \\ &+ \sum_{s=1}^{q} a_{ks}(t)C_{ks}(t)D_S(t)C_{ks}^*(t) \quad (k = 1,...,q). \end{aligned} \qquad (14)$$

determining the change in particular moments of the second order.

References

1. Degtyar S.V., Shusharin Yu.V., Zhuk Ya.O. Motion of Symmetric Gyroscope under Action of Gravity with Discrete Random Change of Parameters of System. // International Applied Mechanics. – 2022. – Vol. 58. – P. 634-644.

2. Degtyar S.V., Shusharin Yu.V., Zhuk Ya.O. Oscillations of a pendulum under the action of random impulses. // International Applied Mechanics. – 2023. – Vol. 59(3). – P. 284–291.

COMPUTER TEACHING SYSTEMS AND LEARNING PROCESS

D.Z. Didmanidze, N. Putkaradze, N.M. Zoidze
Batumi Shota Rustaveli State University, Georgia
Batumi State Maritime Academy, BSMA, Batumi, Georgia

In the traditional teaching process, the teacher is the main source of information in the student / pupil relationship. An important feature in this process is the presence of feedback, which is more or less successfully implemented. We see a completely different picture when using computer technology in the learning process. The main feature that distinguishes this process from the traditional one is the availability to organize an effective dialogue between a person and a computer through interactive programs.

Clearly, e-books have many advantages over traditional textbooks that are reflected in the learning process. However, it also has its downsides, which must be identified and avoided. One of the positive aspects is that the electronic text book, as an emotional tool, has a positive effect on the user's mind, is easily perceived and helps to activate a memorable function. For example, any study topic in a traditional textbook may require a large textual explanation (sometimes even impossible) and still be difficult to comprehend, while for an e-textbook this process is very simple to imagine.

Computer training can be of great help in analyzing the expected accidents of technical equipment and planning appropriate preventive measures to avoid adverse events caused by the accident. Clearly, this can be achieved by reproducing facility or maintenance management statistics and artificially created emergency and contingency simulations on computer trainings. All this should be done in the process of training specialists in higher education, which should be reinforced by the curriculum. Curricula should include the use of e-training in the learning process in the form of visuals, which will model the ongoing technological processes at the facility, which belongs to the field of activity of the future specialist.

THE IMPACT OF INFORMATION TECNOLOGIES ON THE DECISION-MAKING IN SOCIAL ACTIVITIES

I. Sh. Didmanidze, G.D. Tsitskishvili, Marina I. Didmanidze, G.T. Imnaishvili
Batumi Shota Rustaveli State University, Georgia
Batumi State Maritime Academy, Georgia
ibraim.didmanidze@bsu.edu.ge

The present paper outlines modern educational technologies as an integral part of scientific and technical progress, play the increasing role for decisions in a life and activity of a society. And educational technologies find the greatest application. They take a worthy place in all major spheres of a public life and the government. The state in performance of such major function as maintenance of legality and the law and order to aspire to use achievements of scientific and technical development. And consequently to experts in the field of knowledge of jurisprudence, it is necessary to realize a place and a role of modern educational technologies in law-enforcement as some social decision makings of bodies of the government. The paper is devoted to this theme.

The paper emphasizes, that success of any kind of law-enforcement as a social responsibility and public activity in many respects depends on a degree of its maintenance corresponding is long the saved up and systematized information on the crimes accomplished in the past, persons involved in them, means and ways of their fulfillment, various traces of crimes and the objects connected with criminal events, and also from an opportunity and skill of the inspector to use the similar information in the social and public activity, for revealing, search and an identification of their interesting phenomena [1].

The paper discusses, that the social-legal practice is interested in the highly skilled staff delivered by technology education. And without development of the jurisprudence supported by practical check, such specialists to prepare it are impossible. As Georgian Professor Rezo Manvelidze points out in her work “For the Issue of Contemporary Professional Requirements to the Specialist of Service of Marketing” social practice acts as the important criterion of quality check of preparation of specialists, checks the validity, value and an efficiency of scientific research on the basis of which formation is educated “including formation of personal qualities and reception of the expanded circle of knowledge” and “formation of image of the enterprise”; “Practice shows, that the people allocated by commercial abilities, as a rule, are inventive

and vigorous. They prefer to make independently the decisions aimed at reception of concrete results, are susceptible to innovations and ready to risk".

The paper tells that a taken place introduction of programs of the automated technology of judicial office-work can be considered as the first stage in creation of effective system of judicial office-work in law-courts of the general jurisdiction. In a number of perspective technologies of information of courts technologies of recording of judicial sessions and uses of means of "video conferencing" are allocated. The technologies of a video conferencing intended for use by consideration of criminal cases in the cassation order have passed experimental check. The decision of the problem connected with a wide circulation of technology of "video conferencing" [1]. The problem of telecommunication maintenance of information interaction of courts with bodies of the government, legal profession and law enforcement bodies of the Georgian demands the decision.

According to Georgian Philosopher Irma Bagrationi's work "The Issue of Student Distance Communication and Collaboration" information technology "learning can be an "inter-subjective and social process, involving spontaneity and the communal experience of sharing in the learning enterprise" [4] and information centers are head divisions in system of the educational & technological information: maintenance statistical, operatively-help, operatively-search, criminalistics and archival: Education is a basis of cultural-legal, spiritual, social, economic development of a society and the state, "works" on a social practice. There are the interesting social, academic and scientific-research "works in teams to investigate and compare social, environmental, political, cultural aspects of their communities" [4]. Owing to the juridical education the intellectual, creative potential of people is enriched, its cultural level raises, there is maintenance of the qualified specialists in the field of the digital technologies.

The concept provides creation of a uniform information infrastructure of social institutions with stage-by-stage expansion of the general center of information, inter-regional and the regional centers introductions of informational technologies. The centers specified above it is planned to create mainly on the basis of territorial managements of judicial department, having resources necessary for it and experience of information. In these centers groups of highly skilled experts for introduction of new computer technologies in activity of courts, and also support of operation and development of these technologies in a zone of

the responsibility are created. The administrative control, "being a necessary condition of functioning of any economic mechanism, in modern conditions receives the further theoretical development and practical perfection on the basis of improvement of methods of the automated processing of the information methods of decision-making the system analysis" [2]. And, "the role of supporting fundamental structures of valuable empirical experience of progressive traditional technological society are precisely sensitive, delicate, deserving and tactful decisions of the historical political organizations" [3]. It is represented, that formation of the centers with completion by their experts is one of real ways of the decision of such challenge, as personnel maintenance of processes of information in system of courts of the general jurisdiction.

Considering the general decisions of information of social activities it is possible to draw following conclusions: the condition of the majority of courts existing now is characterized by a low level of their equipment means of information, absence of means of information interchange in the electronic form on liaison channels; development and introduction of means of information restrain insufficient financing and absence of the necessary experts providing these processes and operation of educational technologies, equipment of social organization by polytypic means of computer facilities complicates their decisions and realization of their complex information.

References

1. Andryushin, K. Computer Science and Mathematics for Lawyers. – M., "Science", 2002.

2. Bagrationi I. The Impact of Worldview Theory on the Decision Making Process in Business Education// Proceedings of XXXVI International Conference "Problems of Decision Making Under Uncertainties" (PDMU-2021), 2021. – P. 14-16. - URL: http://www.pdmu.univ.kiev.ua/PDMU_2021/PDMU_2021_Skhidnytsia.pdf

3. Bagrationi I. On the Moral Factors of Political Risk in Decision-Making Process// Proceedings of XXXVII International Conference "Problems of Decision Making Under Uncertainties" (PDMU-2022), 2022. – P. 24-26. URL: http://www.pdmu.univ.kiev.ua/PDMU_2022/PDMU_2022_Sheki.pdf

4. Didmanidze I., Bagrationi I. the Issue of Student Distance Communication and Collaboration// Journal "Cross-Cultural Studies: Education and Science (CCS&ES)". – 2018. – Vol.3(1). – P. 6-19. URL: http://j-ccses.org/wp-content/uploads/2018/06/Issue-1-2018.pdf

PROBLEMS OF EMPLOYMENT AND UNEMPLOYMENT

Manana Didmanidze, Ia Motskobili, Anzor Solomonidze
Georgian Technical University, GTU, Tbilisi, Georgia
Batumi Shota Rustaveli State University, BSU, Batumi, Georgia

Unemployment, and especially chronic unemployment, has quite negative socio-economic consequences for society, which is adequately reflected in the standard of living of the population and the process of economic development of the country. Therefore, in international practice, serious attention is paid to the assessment of these negative socio-economic consequences. It is relatively easy to assess the economic consequences of unemployment, while the social consequences, which are difficult to distinguish and are complex and cannot be fully evaluated. The negative consequences of unemployment and the degree of its impact on socio-economic development depend on the situation in the country, on the specific parameters of the social situation.

There are two main methods for determining the number of unemployed:

1. The unemployment rate is determined on the basis of selective observations of a certain part of the population, which is conducted periodically;

2. The unemployment rate can be determined on the basis of applications submitted for the status of unemployed in the state employment services.

It is important that in order to improve the quality of the institutionalization of job search, it is not enough to create Internet portals, regularly organize forums and employment weeks. It is necessary to accelerate the creation of a network of employment promotion centers, which is also provided for by the state strategy for the formation of the labor market.

The analysis of the economic side is important for us, because we believe that different integration or contractual relations between the countries of the world put the economy of this or that country and its individuals in different positions, which can increase their production capacities, as well as reduce them. This is reflected in different ways in the manifestation of the economic cycle and economic growth in a given country.

OPTIMIZATION OF WORKING CAPITAL FLOW

G. Dolenko, D. Manovytska, M. Korobchuk
Taras Shevchenko National University of Kyiv, Ukraine
dolenkogalyna@gmail.com, manovytska_dariia@ukr.net, muha2003199@gmail.com

Given the current requirements of the global business environment, effective working capital management is becoming one of the main advantages for an enterprise. The study of optimization laws of working capital flows is relevant.

$$F(K) = \sum_{i=1}^{4} K_i \to \max,$$

$$R = \sum_{i=1}^{4} \left(\sqrt{\left(\frac{V_i}{V_i^{\max}} \right)^2 + \left(\frac{K_i}{K_i^{\max}} \right)^2} \right) \to \min,$$

$$0 \le V_i \le V_i^{\max},$$

$$K_i^t \ge 0,$$

where

$F(K)$ – is the criterion of profit,

R – is the criterion of the risk of using working capital,

K – denotes the element of working capital,

V – describes cash flows,

t – defines time,

i – is the component of the stage of using working capital.

Research shows that effective working capital management contributes to improving the competitiveness of the enterprise.

References

1. Atril P. Financial Management for Decision Makers. Ninth editions – Pearson, 2020. – 735 p.

MIXTURE OF HIDDEN MARKOV MODELS FOR DATA ANALYSIS

Andriy Drebot
Ivan Franko National University of Lviv, Ukraine
Andrii.Drebot.AMTS@lnu.edu.ua

Hidden Markov Model is a powerful tool for data analysis when it comes to sequence data modelling. With it help we can perform classification and prediction tasks. Usually, it is enough to model the process with one Hidden Markov Model and calibrate the model with picking the right number of hidden states.

However, sequence data can be generated by several underlying processes that are happening simultaneously. That is, we can use the mixture of Hidden Markov Models for better process modelling. This idea is not new and has been already employed for sequence data modelling by researchers.

Existing papers consider two cases of mixture of Hidden Markov Models: all the processes that comprise the mixture have common hidden states; each process has unique set of hidden states (for simplicity, with the same number of states).

In given research, the model does not have such assumptions about hidden states: any processes can share arbitrary part of hidden states with any other process in the mixture. This is the uniqueness of presented paper.

This paper will provide the methodology of model's parameters approximation. Stock market data will be used for testing and evaluating the model. Finally, different configurations of mixtures (different degrees of hidden state's sets overlapping) will be compared.

NON-CLASSICAL BOUNDARY VALUE PROBLEM FOR THE HEAT CONDUCTION EQUATION

Irina Drin[1], Svitlana Drin[2], Yaroslav Drin[3], Mykhailo Lutskiv[4]

[1]Chernivtsi Institute of Trade and Economics of Kyiv National University of Trade and economics, Ukraine

[2]National University of "Kyiv-Mohyla Academy", Ukraine

[3]Yuriy Fedkovych Chernivtsi National University, Ukraine

[4]Ternopil Ivan Puluj National Technical University, Ukraine

irina_drin@ukr.net, svitlana.drin@gmail.com, y.drin@chnu.edu.ua msilence2009@gmail.com

The first boundary value problem for the heat conduction equation was studied in [1]. We provide the first proof of a formula for solving the non-classical boundary value problem, where the temperature is specified at the left end of a homogeneous rod and its flux at the right end.

Let $\varphi(x): R \to R$, $\mu_1, \mu_2: [0,T] \to R$ be continuous and bounded functions, $u(x,t) \in C^{2,1}_{x,t}(R \times [0,T])$. For the problem

$$\frac{\partial u(x,t)}{\partial t} = a^2 \frac{\partial^2 u(x,t)}{\partial x^2}, \ t > 0, \ x \in R,$$
$$u(x,0) = \varphi(x), \ x \in R,$$
$$u(0,t) = \mu_1(t), \ t > 0,$$
$$\frac{\partial u(l,t)}{\partial x} = \mu_2(t), \ t > 0$$

a formula for the solution is established

$$u(x,t) = \sum_{k=1}^{\infty} \frac{\int_0^l \hat{\varphi}(x) \sin\frac{\pi}{l}\left(k-\frac{1}{2}\right)x\,dx}{\int_0^l \sin^2\frac{\pi}{l}\left(k-\frac{1}{2}\right)x\,dx} \exp\left\{-a^2\left(\frac{\pi}{l}\left(k-\frac{1}{2}\right)\right)^2 t\right\} \times$$
$$\times \sin\frac{\pi}{l}\left(k-\tfrac{1}{2}\right)x + \mu_1(t) + x\mu_2(t),$$

where $\hat{\varphi}(x) = \varphi(x) - \mu_1(0) - x\mu_2(0), \ t > 0, 0 < x < l.$

References

1. A.N. Tikhonov, A.A. Samarskiy. Equations of Mathematical Physics. – Nauka, 1972. – 735 p.

STUDY OF NUMERICAL AND ANALYTICAL SOLUTIONS OF A GENERALIZED BOUNDARY VALUE PROBLEM FOR THE HEAT CONDUCTION EQUATION

Irina Drin[1], Svitlana Drin[2], Yaroslav Drin[3], Mykhailo Lutskiv[4]

[1]Chernivtsi Institute of Trade and Economics of Kyiv National University of Trade and economics, Ukraine

[2]National University of "Kyiv-Mohyla Academy", Ukraine

[3]Yuriy Fedkovych Chernivtsi National University, Ukraine

[4]Ternopil Ivan Puluj National Technical University, Ukraine

irina_drin@ukr.net, svitlana.drin@gmail.com, y.drin@chnu.edu.ua msilence2009@gmail.com

In the boundary value problem from [1] let $\varphi(x) = \cos x,\ x \in R$, $\mu_1(t) = \mu_2(t) = 1$. Then, its solution

$$u(x,t) = \sum_{k=1}^{\infty} 2B_k \exp\left\{-\left(\pi\left(k-\frac{1}{2}\right)\right)^2 t\right\} \cdot \sin \pi\left(k-\frac{1}{2}\right)x + x + 1,$$

where

$$B_k = \frac{\pi\left(k-\frac{1}{2}\right) + (-1)^k \sin(1)}{\pi^2\left(k-\frac{1}{2}\right)^2 - 1} - \frac{1}{\pi\left(k-\frac{1}{2}\right)} - \frac{(-1)^{k+1}}{\left(\pi\left(k-\frac{1}{2}\right)\right)^2},$$

we approximately compute it using the Python language and plot it (Fig.1).

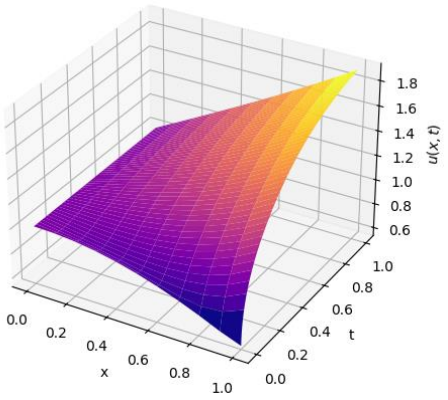

Fig. 1

We compare the values of the analytically found solution with those

obtained by the finite difference method. We compute the relative change expressed in percentages relative to the value found by the analytical method:

$$\Delta u = \frac{u_{FD} - u_A}{u_A} \cdot 100\%,$$

where u_{FD} is the value found by the finite difference method and u_A is the value found by the analytical solution. Let's compare the graphs (Fig. 2).

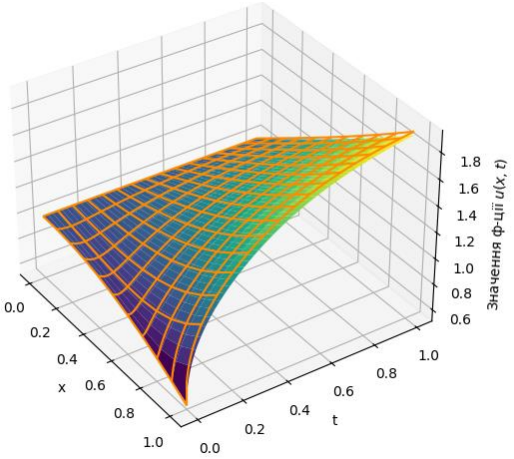

Fig. 2

Thus, the computed values of the solution obtained by the finite difference method and the results of the numerical investigation of the analytical solution of this problem match with maximum and average relative errors of +7.03% and ±1.82%, respectively.

The graphs of the numerical and analytical solutions coincide over the entire range of investigated time and space values.

Further improvements in the accuracy of the numerical solution can be achieved by adjusting grid parameters – reducing spatial step size and increasing the number of computational iterations.

References

1. I. Drin, S. Drin, Y. Drin, M. Lutskiv. Non-classical boundary value problem for the heat conduction equation // International Scientific Conference "Current Issues in Mathematical Modeling and Computational Methods." Kyiv. — 2024.

ARTIFICIAL INTELLIGENCE IS A KEY TECHNOLOGY OF THE FOURTH INDUSTRIAL REVOLUTION

R. Dutsko
Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine
romdsk@gmail.com

The Fourth Industrial Revolution (4IR) is characterized by the convergence of physical, digital, and biological worlds through smart technologies. Artificial intelligence (AI) plays a key role in this process, providing machines with the ability to self-learn, analyze data, and make decisions. It is utilized across various sectors, including manufacturing automation, medical diagnostics, financial analysis, transportation, and many others. AI plays a crucial role in the technological progress that defines the 4IR.

One of the key aspects of this technological revolution is neural networks, which play a pivotal role in driving rapid progress in the field of artificial intelligence. Neural networks enable computers to replicate complex relationships and make sophisticated decisions that were previously considered exclusively human competence.

With the emergence of these new technologies, new opportunities arise for automation in manufacturing, improvement of medical diagnostic methods, development of intelligent learning systems, and many other fields. However, along with these new opportunities come new challenges.

Among these challenges are questions of ethics and safety in the use of artificial intelligence, distribution of resources and access to cutting-edge technologies, as well as the impact on employment and social inequality. To fully harness the potential of technological innovations and ensure their beneficial interaction with society, comprehensive strategies and thorough discussions of all aspects of this process are needed.

Thus, innovations in artificial intelligence and neural networks open up new horizons of possibilities but require careful analysis and management to ensure the stable and effective development of society in this epochal period of technological change[1].

References

1. Iliadis, L., Pimenidis, E. Technologies of the 4th industrial revolution with applications. *Neural Comput & Applic* 35, 21331–21332 (2023). https://doi.org/10.1007/s00521-023-08986-z

MODELING ALGORITHMS FOR RESPONDING TO INFORMATION ABOUT CORRUPTION IN SOCIAL NETWORKS IN THE BUSINESS SPHERE

Irada Dzhalladova, Oleksandr Bartash
Kyiv National Economic University named after Vadym Hetman, Ukraine
idzhalladova@gmail.com

This work examines the construction of models related to algorithms for responding to information about corruption in social networks within the business sphere, which requires a comprehensive approach that includes data analysis from social networks, identification of behavior patterns, and development of response strategies, namely:

1. Data Collection and Analysis: Utilizing social network analytics tools such as Socialinsider, AgoraPulse, Hootsuite to gather data on mentions of corruption [1].
2. Pattern Detection: Analyzing the data to identify behavior patterns that may indicate corrupt activities.
3. Information Dissemination Modeling: Studying existing models of information dissemination and informational impacts in social networks to understand how information about corruption spreads among users [2].
4. Development of Response Algorithms: Creating algorithms that can automatically respond to detected information, for instance, by notifying relevant authorities or publishing rebuttals.
5. Testing and Optimization: Conducting simulations and testing the algorithms to evaluate their effectiveness and make necessary adjustments [3].

The results obtained will help in creating an effective system for responding to information about corruption in social networks, which is essential for maintaining transparency and ethics in the business sphere.

Reference

1. https://vlada-rykova.com/ua/instrumenty-analitiki-socsetej/
2 https://www.researchgate.net/publication/328623512
3. http://www.nbuv.gov.ua/node/1327

MODELING RESPONSE ALGORITHMS TO CYBER THREATS IN CRITICAL INFRASTRUCTURES OF THE BUSINESS SECTOR

Irada Dzhalladova, Anton Stefiienko
Kyiv National Economic University named after Vadym Hetman, Ukraine
idzhalladova@gmail.com

The basis for modeling algorithms is the Cybersecurity Strategy of Ukraine (2021–2025) [1], which outlines the priorities and tasks for ensuring cybersecurity, as well as the National Cybersecurity Cluster, which conducts research and discussions in the field of cybersecurity, the results of which can be used for developing the proposed models [2]. In our work, based on the scientific heritage of Academician O.A. Letichevsky, which encompasses several important developments and promising ideas, including the implementation of insertion modeling of continuous processes [3], we utilize: **algebraic modeling of cybersecurity tasks** to create mathematical models of algorithms for responding to cyber threats; **international practices** for their adaptation to Ukrainian realities; **simulation modeling.**

The use of software for simulating cyberattacks and responses to them allows assessing the effectiveness of algorithms. The experience of institutions such as the U.S. Defense Advanced Research Projects Agency (DARPA), and leading IT companies like Amazon, Google, and Intel has been studied and analyzed, demonstrating that formal methods, particularly the algebraic approach, should form the basis of all modern tools used in the design, research, and analysis of complex systems. A completely new aspect of the work is the use of machine learning and artificial intelligence tools for predicting and responding to cyber threats.

Reference

1. Cybersecurity Strategy of Ukraine (2021 – 2025): https://www.rnbo.gov.ua/files/2021/STRATEGIYA%20KYBERBEZPEKI/proekt%20strategii_kyberbezpeki_Ukr.pdf
2 The Most Relevant Research in the Field of Cybersecurity in Ukraine and the World – 2020–2021 | National Cybersecurity Cluster (cybersecuritycluster.org.ua)
3. Letichevsky A. Algebraic Interaction Theory and Cyber-Physical Systems. Journal of Automation and Information Sciences. 2017. 49(9): 1–19. DOI: https://doi.org/10.1615/JAutomatInfScien.v49.i9.10

ON THE APPLICATION OF INTERNET OF THINGS IN THE DEVELOPMENT OF COMPUTER SYSTEMS FOR SEMI-NATURE MODELING

V. Eresko, V. Vyshinskiy, A. Vyshinskaya, A. Kononenko, A. Slipets
Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine
fkp500@i.ua, vyshinskiy@ukr.net, vyshinskaya@ukr.net, kononenko17@i.ua, alla_volod@ukr.net

The creation of modern complex objects necessitates research and semi-natural modeling of individual elements and typical components of these objects. To automate research processes, provide hardware and information support for solving problems of semi-natural modeling of such elements and components of an object, complex distributed computer systems are created. The modularity of such systems, virtualization of their components, and the use of intelligent interfaces make it possible to ensure joint uninterrupted operation of system components in real time, convenient monitoring and management of research processes and semi-natural modeling of elements of complex objects in various fields.

Currently, a lot of hardware and software for the Internet of Things (IoT) have appeared on the computing market. In most cases, these are standard controllers, microcomputers, intelligent sensors and other means for embedding in various objects. Such modern technical means are convenient to use when creating distributed computer systems and intelligent interfaces of their individual components for semi-natural modeling of complex objects. The presence of various hardware interfaces for IoT devices makes it possible to make system components more autonomous, reliable and efficient in processing information. You can also use the most convenient communication technologies in each specific case. And convenient visualization of the required technological process in intermediate sections of the system makes it possible to facilitate the processes of research and semi-natural modeling of the entire object using standard software and hardware available to the user.

The use of standard Internet of Things devices also makes it possible to ensure joint uninterrupted operation in real time of a large number of heterogeneous tools and various equipment, support multitasking, and provide access to various data sources in real time to control complex technological processes. This can also be crucial for accelerating and reducing the cost of computer system development processes, further technology development, and significantly increasing the efficiency of computer systems for semi-natural modeling.

AI AS AN EXPERT IN DECISION MAKING

B. Fil
Ivan Franko National University of Lviv, Ukraine
bohdan.fil@lnu.edu.ua

Finding experts for assessments is a time-consuming hurdle in decision-making. AI offers a solution by generating expert-level evaluations. While constantly evolving AI systems make pinpointing the "best" one difficult, we can explore the pros and cons of using AI as an expert.

Advantages:

- Combines and analyzes vast amounts of expert knowledge.
- Delivers consistent, unbiased assessments due to large datasets.
- Offers speed and efficiency even with limitations and uncertainties.
- Identifies hidden patterns humans might miss.
- Helps overcome cognitive biases.

Disadvantages:

- Low trust due to lack of user experience and "black box" nature of AI.
- Limitations in handling complex or novel problems.
- Difficulty in formalizing and potentially limiting assessments.
- Challenges in guaranteeing data accuracy and neutrality.
- Potential trust issues with results, especially in critical decisions.
- Requires ethical and social considerations to maximize benefits and minimize risks.

AI as a Supplement:

It is important to note that AI will not replace human intelligence, but will only supplement it, helping to make more informed and effective decisions in standard (average) situations. In non-standard and new situations, a person who uses AI as an auxiliary tool will be more effective as AI. AI as an expert should be treated as an "exoskeleton", more precisely, an "exobrain" that strengthens a person but does not replace it.

References

1. Duan, Y., Edwards, J. S., & Dwivedi, Y. K. (2019). Artificial intelligence for decision making in the era of Big Data—Evolution, challenges and research agenda. *International Journal of Information Management, 48,* 63–71.

2. Goniukova, L., & Surzhyk, M. (2022). Models and methods of public administrative decision-making. *Public Administration and Regional Development*, (18), 1266-1280

THE APRIORI ESTIMATES AND REGULARITY OF SOLUTIONS THE NONLINEAR ELLIPTIC EQUATIONS IN GENERALIZED MORREY SPACES

T.S. Gadjiev[a,b,c]

[a]Institute of Mathematics ad Mechaniks, Baku, Azerbaijan
[b]Azerbaijan Architecture and Construction University, Baku, Azerbaijan
[c]Sumqait State University, Sumqait, Azerbaijan
tgadjiev@mail.az

Mathematics Subject Classification 35J25, 35K20, 46E30.

Keywords: Nonlinear parabolic equation; regularity; Reifenberg flat domain; fractional maximal operator; generalized Morrey spaces; Calderón- Zygmund estimates.

In this paper, we prove the generalized Morrey estimates for the gradient of weak solutions for a class of nonlinear parabolic equations in a very general irregular domain. The nonlinearity is assumed to be merely measurable only in the time variable t and belongs to the small BMO class as functions of the spatial variable x.

The aim of this study is to investigate the regularity properties of solutions to the following Dirichlet problem

$$u_t - div\, a(x, Du) = div\, f \quad \text{in} \quad \Omega,$$

$$u = 0 \ \text{on} \ \partial\Omega,$$

where Ω is a bounded open domain in R^n, $n \geq 2$.

GOOGLE CHROME BROWSER EXTENSION FOR DXTRADE TRADING PLATFORM FOR FOREX

O. Galkin, O. Anikanov
Taras Shevchenko National University of Kyiv, Ukraine
o.galkin@knu.ua

The Forex market [1] is the largest financial market in the world. Forex brokers and traders utilize various trading platforms to conduct operations, among which the DXtrade platform [2] stands out due to its functionality and flexibility. However, there is a need to enhance tools for analyzing and managing trading positions, enabling traders to make more informed decisions and minimize risks. This can be achieved through the development of specialized browser extensions that integrate with existing platforms and provide additional capabilities.

The relevance of developing such extensions for DXtrade-based trading platforms lies in their ability to dynamically recognize brokers and modify web pages by adding custom charts and tools for opening positions with enhanced parameters. Such extensions are essential tools for modern trading, allowing traders to more effectively manage risks using parameters such as risk rate, risk/reward, take-profit zones, and stop-loss. Importantly, they provide risk visualization, making the decision-making process more transparent and well-founded.

We propose a Google Chrome browser extension that integrates custom interactive components into trading platforms that use the DXtrade project as their core. Its key implementation features are:

– support for an unlimited number of brokers using DXtrade;
– customization of interactive components;
– handling scenarios where key API elements are missing or malfunctioning.

An intuitive and movable toolbar was created, allowing users to manage risks and positions directly from the chart. Significant upgrades were made to the position manager. Functionality for Break Even and partial position closure was added, as well as the ability to work with a group of positions.

The system can be easily integrated with other larger systems with similar functionality, or developed into a standalone independent product.

References

1. Noonan T. Forex Trading QuickStart Guide. – ClydeBank Media LLC, 2022. – 342 p.
2. DXtrade Project Portal [Електронний ресурс]. – Режим доступу: URL: https://dx.trade

REGULAR ELEMENTS OF SEMIGROUP $B_X(D)$ DEFINED BY SEMILATTICES OF CLASS $\Sigma_2(X,4)$

Omar Givradze, Tengiz Didmanidze
Batumi Shota Rustaveli State University, Georgia

Let $B_X(D)$ be a complete semigroup of binary relations defined by semilattice $D=\{Z_1,Z_2,Z_3,Z_4\}$, of class $\Sigma_2(X,4)$ ([2]).

We consider the regular elements of this semigroup $B_X(D)$.

Theorem. Let $D=\{Z_1,Z_2,Z_3,Z_4\}\in\Sigma_2(X,4)$. Then element α of semigroup $B_X(D)$ is a regular element of this semigroup, if and only if it satisfies at least one of the following conditions:

a) $\alpha=X\times Z_i$, where i=1,2,3,4;

b) $\alpha=(Y\times Z_i)\bigcup((X\setminus Y)\times Z_j)$ $\alpha=(Y\times Z_i)\bigcup((X\setminus Y)\times Z_j)$, where $i=1,2,3$, j=3,4, $i<j$, $Y\subset X$ and satisfies the conditions: $Z_4\setminus Y\neq\varnothing$ and $Y\supseteq Z$, where $Z\in\{Z_1,Z_2,Z_3\}$;

c) $\alpha=(Y\times Z_1)\bigcup((X\setminus Y)\times Z_2)$, where $Y\subset X$ and satisfies the conditions: $Z\subseteq Y\subseteq X\setminus Z'$, where $Z,Z'\in\{Z_1,Z_2\}$, $Z\neq Z'$;

d) $\alpha=(Y_1\times Z_i)\bigcup(Y_2\times Z_3)\bigcup((X\setminus(Y_1\bigcup Y_2))\times Z_4)$, where $i=1,2$, $Y_1,Y_2\subset X$ and satisfy the conditions: $Y_1\bigcap Y_2=\varnothing$, $Y_1\bigcup Y_2\supseteq Z_3$, $Y_2\bigcap Z_3\neq\varnothing$, $Z_4\setminus(Y_1\bigcup Y_2)\neq\varnothing$ and $Y_1\supseteq Z$, where $Z\in\{Z_1,Z_2\}$;

e) $\alpha=(Y_1\times Z_1)\bigcup(Y_2\times Z_2)\bigcup((X\setminus(Y_1\bigcup Y_2))\times Z_3)$, where $Y_1,Y_2\subset X$ and satisfy the conditions: $Y_1\bigcap Y_2=\varnothing$, $Y_1\bigcup Y_2\neq X$, $Z\subseteq Y_1\subseteq X\setminus Z'$ and $Z'\subseteq Y_2\subseteq X\setminus Z$, where $Z,Z'\in\{Z_1,Z_2\}$, $Z\neq Z'$;

f) $\alpha=(Y_1\times Z_1)\bigcup(Y_2\times Z_2)\bigcup((X\setminus(Y_1\bigcup Y_2))\times Z_4)$, where $Y_1,Y_2\subset X$ and satisfy the conditions: $Y_1\bigcap Y_2=\varnothing$, $Z_4\setminus(Y_1\bigcup Y_2)\neq\varnothing$, $Z\subseteq Y_1\subseteq X\setminus Z'$ and $Z'\subseteq Y_2\subseteq X\setminus Z$, where $Z,Z'\in\{Z_1,Z_2\}$, $Z\neq Z'$;

g) $\alpha=(Y_1\times Z_1)\bigcup(Y_2\times Z_2)\bigcup(Y_3\times Z_3)\bigcup((X\setminus(Y_1\bigcup Y_2\bigcup Y_3))\times Z_4)$, where $Y_1,Y_2,Y_3\subset X$ and satisfy the conditions: $Y_i\bigcap Y_j=\varnothing$, when $i\neq j$ $(i,j=1,2,3)$, $Z_4\setminus(Y_1\bigcup Y_2\bigcup Y_3)\neq\varnothing$, $Z\subseteq Y_1\subseteq X\setminus Z'$ and $Z'\subseteq Y_2\subseteq X\setminus Z$, where $Z\neq Z'$;

Consequence. Let $D=\{Z_1,Z_2,Z_3,Z_4\}\in\Sigma_2(X,4)$. The number of elements in the set R of all regular elements of the finite semigroup

$B_X(D)$ is calculated by the formula:

$$|R| = 5 \cdot \left(2^{|X \setminus Z_1|} + 2^{|X \setminus Z_2|} - 2^{|X \setminus Z_3|} - 2^{|X \setminus Z_4|}\right) + 2 \cdot 4^{|X \setminus Z_4|} \cdot \left(4^{|Z_4 \setminus Z_3|} - 3^{|Z_4 \setminus Z_3|}\right) +$$

$$+ 2 \cdot 3^{|X \setminus Z_3|} + 3^{|X \setminus Z_4|} \cdot \left(3^{|Z_4 \setminus Z_3|} - 2^{|Z_4 \setminus Z_3|}\right) \cdot \left(2^{|Z_3 \setminus Z_1|+1} + 2^{|Z_3 \setminus Z_2|+1} - 4\right) + 4.$$

References

1. Diasamidze Ya., Makharadze Sh. Complete semigroups of binary relations. – Turkey, Kriter, 2013. – 519 p.

2. Givradze O. Irreducible Generating Sets of Complete Semigroups of Unions $B_X(D)$ Defined by Semilattices of Class $\Sigma_2(X,4)$ // Journal of Mathematical Science. – 2012. – Vol.186(5). – P.745-750.

PETRI NET SYSTEM IN PRACTICE

P. Grochowalski, Z. Suraj Z., P. Drygaś
University of Rzeszów, Poland
{pgrochowalski, zsuraj, padrygas}@ur.edu.pl

Concurrent systems such as manufacturing systems, control systems, communication systems and decision support systems are becoming increasingly important in the modern world. Designing these systems requires modeling and analysis to achieve desired performance, reduce costs, and avoid catastrophic errors.

Petri nets are widely used in both theoretical analysis and practical modeling of concurrent systems, mainly due to their rigorous modeling and formal analysis techniques. However, their practical use requires access to specialized tools [1].

The aim of this report is to discuss the structure and functional capabilities of the Petri Net System (PNeS for short) in the area of modeling and analysis of general-purpose systems, decision support systems and robot control systems [2].

References

1. Jie, T. W., Ameedeen, M. A.: A Survey of Petri Net Tools. *Lect.Notes in Electr.Eng.*, vol. 315, pp. 537-551, Springer, 2015.

2. Suraj, Z., Grochowalski, P.: PNeS in Modelling, Control and Analysis of Concurrent Systems. *Lect.Notes in Artif. Intell.*, vol. 12872, pp. 279-309, Springer Nature, 2021.

THE PROBLEM OF ENSURING THE FUNCTIONAL STABILITY OF ORGANIZATIONAL SYSTEMS ON ORDINARY SCALE UNDER CONDITIONS OF UNCERTAINTY

O. Hnatiienko, H. Hnatiienko
Taras Shevchenko National University of Kyiv, Ukraine
oleksii.hnatiienko@knu.ua, hnatiienko@knu.ua

The task of ensuring stable functioning of the organizational system in conditions of uncertainty is considered and investigated. Today, there is a large number of system organizations in the world, which are well structured, have perfectly described, formalized and implemented business processes [1]. At the same time, personnel decisions even in such organizations are usually made spontaneously, sometimes voluntarily, and largely depend on the level of training of the person making the decision. The incompleteness of expert information is a natural phenomenon, which often occurs in practice and is one of the types of uncertainty along with vagueness, inaccuracy, unreliability, uncertainty, incorrectness, inadequacy, inadequacy, etc. The incompleteness of data and the impossibility of supplementing it naturally accompanies experts and decision-makers in their activities in various subject areas [1].

A promising direction of scientific research is the application of functional stability for personnel management systems. In the framework of the indicated direction, it is necessary to investigate the application of multi-criteria optimization, fuzzy logic, expert technologies for managing the organizational system in conditions of uncertainty.

The objects of ensuring the functional stability of the organization are management technologies, personnel of the organization, financial means, material assets, production technologies, business processes, information resources, etc. Options for duplicating functions, operational interchangeability of subsystems, and choosing the optimal configuration of the organizational system to increase functional stability should also be provided for.

References

1. Hnatiienko H., Snytyuk V., Tmienova N., Zatonatskiy D. and Zhylinska O. Mathematical Support of the Task of Determining the Strategic Directions of Development and Priorities of the Organization / CEUR Workshop Proceedings, Volume 3347, Pages 169 – 184, 2022 // 9th International Scientific Conference "Information Technology and Implementation", IT and I 2022, Kyiv, November 30 - December 02, 2022.

MINIMIZING UNCERTAINTY IN FORECASTING SUNFLOWER YIELDS ASSOCIATED WITH THE PRESENCE OF CLOUDS IN SATELLITE IMAGES

V. Hnatiienko, H. Hnatiienko
Taras Shevchenko National University of Kyiv, Ukaraine
vladgnat1483@gmail.com, hnatiienko@knu.ua

The problem of predicting sunflower yield under conditions of uncertainty was studied. Traditional sunflower yield forecasting systems use satellite images selected from the entire time range based on cloud cover [1]. This approach contains a large number of uncertainties that affect the accuracy and quality of decision-making. In particular, an image may be rejected even if it contains only 20% clouds, as such data is considered distorted. In some periods of the year, only about 5 valid images remain for analysis from the observation range of 100 days. This creates uncertainty about the presence and influence of clouds in each particular image, and also impairs forecasting due to the loss of important information at critical stages of the growing season. In addition, there are uncertainties associated with the weather forecast and the relationship between the values of the vegetation indices and the actual harvest.

In order to solve the problems contained in predictive yield forecasting systems, the authors suggest using all satellite images of sunflower crops by introducing an additional stage of processing cloudy areas. The model that implements the proposed approach can be presented in two parts [1]:

1. Neural network for cloud recognition indicating which pixels:

1a) contain clouds and their shadows;

1b) consist of pure data with reflected solar radiation from the field.

For this, a computer vision model such as U-Net can be used to perform the segmentation.

2. Recovery of lost data using interpolation. In cases where cloud is present on an image pixel for several consecutive days, or when pixels need to be reconstructed based on data acquired on subsequent days, polynomial interpolation or splines can be used.

References

1. Hnatiienko, V. H., Hnatiienko, H. M., Zozulya, O. L. & Snytyuk, V. Ye. (2024). The method of forecasting the yield of agricultural crops using multifactorial analysis and neural networks. // Scientific Bulletin of Uzhhorod University. Mathematics and Informatics Series, 44(1), 93–105. https://doi.org/10.24144/2616-7700.2024.44(1).93-105

GAMIFICATION OF DIGITAL EDUCATIONAL MATERIALS

Hlib Holubov, Anatolii Pashko
Taras Shevchenko National University of Kyiv, Ukraine
holubovhlib.gd@gmail.com, aapashko@gmail.com

Video games and digital tools are effective means to increase the interest of learners [1]. Gamification of the educational process can be used to simplify the education of complex disciplines and the assimilation of new knowledge while maintaining academic performance [2]. The efficiency of using digital materials and serious educational video games depends on the previous experience of using similar applications, the preparation of educational materials, and the design of educational applications [3, 4].

The paper considers the possibility of using gamification in the educational process of a higher educational institution, in particular, when studying individual sections of discrete mathematics.

References

1. Kuo-Wei L. Effectiveness of gamification and selection of appropriate teaching methods of creativity: Students' perspectives / Kuo-Wei L. // Heliyon. – 2023. – Vol.8(10). – id. e20420.

2. Cattoni A. How to improve reading and writing skills in primary schools: A comparison between gamification and pen-and-paper training / Cattoni A., Anderle F., Venuti P., Pasqualotto A. // International Journal of Child-Computer Interaction. – 2024. – Vol.39. – id. 100633.

3. Fathema N. Expanding the Technology Acceptance Model (TAM) to Examine Faculty Use of Learning Management Systems (LMSs) In Higher Education Institutions / Fathema N., Shannon D., Ross M. // MERLOT Journal of Online Learning and Teaching. – 2015. – Vol.11(2). – P. 210-232.

4. Krappala K. Achievers, Explorers, Wanderers, and Intellectuals: Educational Interaction in Minecraft Open-World Action-Adventure Game / Krappala K., Kemppinen L., Kemppinen E. // Computers and education open. – 2024. – Vol.6. – id. 100172.

INITIATION OF ELECTRON CAPTURE BY DEEP CENTERS

O.M. Janelidze, I. G. Takidze
Batumi Shota Rustaveli State University, Georgia
Batumi State Maritime Academy, Georgia

This work proposes a mechanism involving an excited deep center's participation in electron scattering and capture. The sinusoidal voltage waveform was monitored on an oscilloscope. No fundamental differences were observed between studies conducted in pulsed and quasi-continuous modes. The hysteresis loop areas of the S-shaped and N-shaped sections depend on the sample.

In the S-shaped section, a sharp "step-down" (current step-up) appears on the U-shaped voltage pulse. Conversely, in the N-shaped section, a step appears in the voltage pulse ("up") and current ("down"). The front of the step in the N-shaped section is characterized by a steep slope. As the power applied to the sample increases, the steps synchronously shift to the left until they completely disappear. Starting with a power level that induces the S-shaped section, measurements are accompanied by strong ultrasound (whistle), increasing in both power and frequency.

Low-frequency oscillations occur on the pulse steps in the N-shaped section. The measurements were conducted in an electrical circuit with a low-quality factor. The threshold current value for forming the N-shaped region suggests that electron capture is performed by a deep center with an energy level located 0.345 eV below the conduction band's edge. The accumulation of energy from the lattice's main atoms' longitudinal acoustic vibrations increases the amplitude and frequency of impurity atoms' vibrations.

The vibration amplitude is limited by the crystal's unit cell size. The hysteresis in the N-shaped region is explained by the low voltage maintaining the recombination domain and the sufficient stability of the centers' excited states after removing degeneracy. At voltages lower than position 6, domains cannot exist. With increasing temperature, the energy of localized phonons rises, leading to stronger ultrasonic energy pumping into deep centers and an increased dipole moment of quantum transitions within the excited complex. This raises the amplitude of the center atoms' vibrations, increasing the likelihood of collisions with drifting electrons.

ASYMPTOTIC ANALYSIS OF OPTIMAL CONTROL PROBLEMS ON THE SEMIAXES FOR CARATHÉODORY DIFFERENTIAL INCLUSIONS WITH FAST OSCILLATING COEFFICIENTS

O. Kapustyan, T. Zhuk
Taras Shevchenko National University of Kyiv, Ukraine
kapustyan@knu.ua, zhuktetiana6@gmail.com

In this paper we investigate the long-term behavior of control systems characterized by differential inclusions with rapidly changing coefficients. The primary focus is on differential inclusions of the Carathéodory type, which are defined as differential equations whose right-hand sides are set-valued maps and depend on both the current state and control variables.

The study addresses an optimal control problem on a semiaxis, incorporating a coercive cost functional and time-dependent coefficients that oscillate quickly. The authors show that as a small parameter, indicative of the oscillation frequency, approaches zero, the solution to the control problem converges to a solution of a simplified problem with averaged coefficients. This averaging process is interpreted in the sense of the Kuratowski upper limit, which helps in understanding the convergence of set-valued maps.

Acknowledgements. This research was supported by NRFU project No. 2023.03/0074 "Infinite-dimensional evolutionary equations with multivalued and stochastic dynamics"

References

1. Dashkovskiy S., Kapustyan O., Kapustian O., Zhuk T. Asymptotic analysis of optimal control problems on the semiaxes for Carathéodory differential inclusions with fast oscillating coefficients Nonlinear Analysis // Modelling and Control. – 2023. – Vol. 28(6). – P. 1077–1088. URL: https://doi.org/10.15388/namc.2023.28.33435

INTERPOLATION AND KOLMOGOROV-GABOR POLYNOMIALS

O. F. Kashpur
Taras Shevchenko National University of Kyiv, Ukraine
olena.kashpur@knu.ua

Kolmogorov-Gabor polynomials are used in solving so applied problems: modeling and forecasting of business processes, modeling of complex hydrological processes [1], training of neural networks [2], economic processes, etc. To construct these polynomials, Group Method of Data Handling is used [1]. Polynomials of this form can be renewed based on the interpolation formulas

$$f(x_1, x_2, \dots, x_n) = \sum_{k=0}^{n} \sum_{i_1,\dots,i_k=1}^{m} a_{i_1 \dots i_k} x_{i_1} \dots x_{i_k},$$

where the unknown coefficients $a_{i_1 \dots i_k}, k = \overline{1,n}$, are based on recursion relations for the given values of the function $f(\gamma_i), i = \overline{1,m}$, at the nodes $\gamma_i, i = \overline{1,m}$ [3, 4]. Interpolation nodes $\gamma_i, i = \overline{1,m}$, from the set $\{\gamma_0 = e_0,\ \gamma_i = e_{i_1} + \dots + e_{i_k},\ k = \overline{1,n}, i_j = \overline{1,m},\}$, where $e_k, k = \overline{1,m}$ - an orthonormal system of elements.

Note that the degree of the polynomial n and the number of interpolation nodes m are unrelated. It is shown that if the number of interpolation nodes m coincides with the dimension of the space of polynomials, then we will get an exact solution to the given problem: the Kolmogorov-Gabor polynomial we are approximating will coincide identically with the interpolation polynomial.

References

1. Wang X., Li L., Lockington D., Pullar D., D-S Jeng. Self-Organizing Polynomial Neural Network for Modelling Complex Hydrological Processes. – Department of Civil Engineering, Research Report R861.
2. Madala H.R., Ivakhnenko A.G. Inductive Learning Algorithms for Complex Systems Modeling. – CRC Press, 1994. – 364 p.
3. Kashpur O., Khlobystov V. Invariance and uniqueness of solutions polynomial interpolation problems in Euclidean space //Journal of Comp. and Applied Mathematics. – 2015. – Vol. 2(119). – P.8-14.
4. Khlobystov V., Kashpur O. On interpolation of polynomial operators // Cybernetics and Systems Analysis. – 1996. – Vol.32(3). – P.398-403.

SOLVING THE PROBLEM OF TRACKING THE PENETRATION OF OBJECTS INTO PROHIBITED ZONES USING MACHINE LEARNING

A.O. Kharina, A.S. Slabospitsky
Taras Shevchenko National University of Kyiv, Ukraine
vernik03@gmail.com, sl@univ.kiev.ua

This work is devoted to opportunity research of computer vision algorithms for development of a system for monitoring the behaviour of pets in indoor environments. The main tool for achieving the goal was the use of deep learning methods based on the TensorFlow platform.

The performed work covers the approbation and comparative analysis of the capabilities of known computer vision algorithms for tracking moving objects, applications and methods of training models, as well as data collection and creation of a customizable data set taking into account the specifics of the task (35 686 images in total), long-term training models on the TensorFlow platform and developing own application.

Training dataset includes images of dogs, cats and humans with information about their position on image. This data is enough for the neural network to recognize the size and position of people and pets in the video stream. Neural network was trained with TensorFlow Light run in Google Colaboratory service.

As a result, the Python application using this trained neural network is able to track pets because it recognizes domestic animals and people separately and only reacts to pets.

The application allows the user to independently define areas that are prohibited for pets. The user also has a wide range of sound signals to choose from, in order to warn or scare away the pet if it has entered the prohibited area. OpenCV and Tkinter libraries were used to process the video stream and create the application interface, respectively.

The quality of the developed system is evaluated using standard indicators such as accuracy, recall and F_1 score. The results of the experiments confirm the high performance of the system and its ability to effectively detect and track illegal movements of pets.

The presented work confirms the possibility of successfully solving the task of tracking pets using machine learning and computer vision methods. And the use of the TensorFlow framework provides effective training of deep learning models and contributes to the achievement of the research goal.

DECISION-MAKING IN A FUZZY ENVIRONMENT: IMPLICATIONS FOR EDUCATIONAL ISSUES

Ia Khasaia, Ibraim Didmanidze, Didar Didmanidze
Batumi Shota Rustaveli State University, Georgia

In educational settings, decision-making often occurs in environments characterized by uncertainty. Traditional decision-making models relying on precise information, frequently tend to fall short in these dynamic contexts. The article explores the concept of decision-making in a fuzzy environment, where information is inherently imprecise, incomplete, or both. The study delves into the principles of fuzzy logic and fuzzy set theory, presenting them as valuable tools for navigating the uncertainties prevalent in educational systems.

By examining specific case studies and theoretical frameworks, the article illustrates how fuzzy decision-making models can be effectively applied across various educational domains. In educational leadership, these models enable administrators to make more flexible and adaptive decisions, particularly in resource allocation and strategic planning. In policy formulation, fuzzy logic aids in balancing competing interests and predicting policy outcomes amidst uncertain future conditions. For curriculum development, fuzzy decision-making facilitates the creation of responsive and inclusive curricula that cater to diverse student needs and evolving educational standards. Within classroom management, fuzzy approaches help teachers assess and respond to complex student behaviors and learning needs with greater nuance and sensitivity.

The article discusses the broader implications of adopting fuzzy decision-making approaches, emphasizing their potential to enhance the adaptability and responsiveness of educational practices. By addressing the nuanced challenges faced by educators, administrators, and policymakers, fuzzy decision-making models contribute to the development of more resilient and effective educational systems. The adoption of these models is presented as crucial for fostering environments that can better accommodate the diverse and dynamic needs of students in today's rapidly changing educational landscapes.

HARNESSING THE INDUSTRIAL INTERNET OF THINGS (IIOT) FOR ADVANCED HARDWARE-IN-THE-LOOP (HIL) SIMULATION AND DIGITAL TWIN OPTIMIZATION

A. Khudiakov
Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine
akhudiakov97@gmail.com

The Industrial Internet of Things (IIoT) has emerged as a transformative force in modern industry, revolutionizing the way enterprises collect, analyze, and utilize data. By connecting a vast network of sensors, actuators, and other devices, the IIoT enables unprecedented levels of automation, optimization, and insight. This thesis delves into the integration of IIoT technologies with Hardware-in-the-Loop (HIL) simulation to create sophisticated digital twins of industrial systems.

The foundation of this approach lies in the real-time integration of sensor data from IIoT devices into HIL simulations. By mirroring the behavior of physical assets within a virtual environment, digital twins provide a powerful platform for testing, analysis, and optimization. The fidelity of these digital twins is significantly enhanced by the continuous influx of real-world data from the IIoT, enabling a more accurate representation of system behavior.

One of the most promising applications of this technology lies in the realm of predictive maintenance. By analyzing real-time equipment data within the HIL simulation environment, we can identify patterns and anomalies that may indicate impending failures. This enables proactive maintenance interventions, reducing downtime, optimizing maintenance schedules, and extending the lifespan of critical assets.

Furthermore, the integration of IIoT data with HIL simulations opens new avenues for anomaly detection and performance optimization. Machine learning algorithms can be applied to the vast datasets generated by IIoT devices to identify deviations from normal operating conditions. This allows for early intervention and corrective action, preventing costly failures and ensuring optimal system performance.

The potential impact of this technology extends beyond the factory floor. By incorporating IIoT data from across the supply chain, we can create digital twins that offer insights into logistics, inventory management, and demand forecasting. This holistic view can lead to improved efficiency, reduced costs, and enhanced responsiveness to market fluctuations.

However, the widespread adoption of IIoT in industrial settings presents several challenges. Data security and privacy are paramount concerns, as the sensitive nature of industrial data demands robust protection against unauthorized access and cyberattacks. Additionally, the sheer volume and complexity of IIoT data require sophisticated data management and processing techniques to ensure meaningful insights can be extracted.

Looking towards the future, emerging technologies such as edge computing and artificial intelligence (AI) hold great promise for enhancing the capabilities of IIoT-enabled HIL simulations. Edge computing can enable real-time data processing and analysis closer to the source, reducing latency and improving responsiveness. AI algorithms can be applied to uncover hidden patterns and correlations within IIoT data, enabling more accurate predictions and further optimization of industrial processes.

In conclusion, the convergence of the IIoT and HIL simulation represents a paradigm shift in how industries design, operate, and maintain complex systems. By harnessing the power of real-time data, we can create digital twins that accurately reflect the behavior of physical assets, leading to improved efficiency, reduced downtime, and ultimately, a more sustainable and resilient industrial ecosystem.

ESTIMATIONS OF SOLUTIONS IN DYNAMICAL SYSTEMS WITH UNCERTAIN TIME-DELAY OF NEUTRAL TYPE

D. Khusainov[1], A. Shatyrko[1], R. Mustafaeva[2]
[1]Taras Shevchenko National University of Kyiv, Ukraine
[2]Karakalpak State University, Nukus, Uzbekistan
d.y.khusainov@gmail.com, shatyrko.a@knu.ua
raxmustafaeva@gmail.com

The report discusses linear differential-difference equations of neutral type. The research method chosen was the second Lyapunov method using Lyapunov-Krasovsky functionals. Constructive estimates are given for solutions of linear stationary equations of the form

$$\frac{d}{dt}[x(t)-dx(t-\tau)]=-ax(t)+bx(t-\tau),\ \ t\geq 0 \qquad (1)$$

It is required to obtain a majorant estimate of the deviation of the solution $x(t)$ of system (1) from the equilibrium position in the interval

$-\tau \le t \le T_N$, $T_N = m_N \tau$.

To obtain estimates of the convergence of solutions, the functional is used

$$V_0[x(t)] = x^2(t) + \int_{t-\tau}^{t} e^{-\beta(t-s)}\{g_1 x^2(s) + g_2 \dot{x}^2(s)\}ds,$$

$$g_1 > 0,\ g_2 > 0,\ \beta > 0.$$

Theorem. If matrix

$$S[\beta, g_1, g_2] = \begin{bmatrix} 2a - g_1 - a^2 g_2 & -b(1-ag_2) & -d(1-ag_2) \\ -b(1-ag_2) & e^{-\beta\tau} g_1 - b^2 g_2 & -bdg_2 \\ -d(1-ag_2) & -bdg_2 & \left(e^{-\beta\tau} - d^2\right) g_2 \end{bmatrix}$$

is positive-definite, then trivial solution of (1) is exponential stable in the metrics C^1. Moreover, the following convergence estimate is valid:

$$|x(t)| \le [(1+\tau\sqrt{g_1})\|x(0)\|_\tau + \tau\sqrt{g_2}\,\|\dot{x}(0)\|_\tau]e^{-\frac{1}{2}\gamma t},$$

$$|\dot{x}(t)| \le [(\frac{|b|}{|d|} + M(1+\tau\sqrt{g_1}))\|x(0)\|_\tau + (1+M\tau\sqrt{g_2})\|\dot{x}(0)\|_\tau]e^{-\frac{1}{2}\varsigma t},$$

where $M = \dfrac{|ad-b|}{1-|d|e^{\frac{1}{2}\gamma\tau}} e^{\frac{1}{2}\gamma\tau}[1-(|d|e^{\frac{1}{2}\gamma\tau})^{m-1}]$,

$\gamma = \min\{\lambda_{\min}(S[\beta, g_1, g_2]), \beta\}$, $\varsigma = \min\{\dfrac{2}{\tau}\ln\dfrac{1}{|d|},\ \gamma\}$.

References

1. Bellman Richard, Cooke Renneth L. Differential-Difference Equations. – Academic Press, New York-London, 1963.

2. Hale Jack K., Verduyn Lunel Sjoerd M. Introduction to Functional Differential Equations. – Springer-Verlag, New-York-Berlin-Ytidelberg-London-Paris, 1991.

EXACT SOLUTIONS OF ONE NONLINEAR DYNAMICAL SYSTEM

K. T. Kolba, M. M. Prytula
Ivan Franko National University of Lviv, Ukraine
khrystyna-yaryna.kolba@lnu.edu.ua
mykola.prytula@lnu.edu.ua

During the past four decades or so searching for explicit solutions of nonlinear evolution equations by using various different methods is the main goal for many researchers. These equations are mathematical models of complex physical occurrences that arise in engineering, chemistry, biology, mechanics and physics. In mathematical physics, finding the exact solutions of such equations reveals the salient features of the inner mechanism of possibly hidden complex physical phenomena. Many powerful methods to construct exact solutions of nonlinear evolution equations have been established and developed such as the inverse scattering transform, the Backlund-Darboux transform, the Hirota's bilinear operators, the homogeneous balance method and more [1].

In the present work we will consider to solve one nonlinear dynamical sytem [2] by using the (G'/G)-expansion method which is introduced by Mingliang Wang, Xiangzheng Li and Jinliang Zhang [3].

$$\begin{cases} u_t = u_{xxx} + 4uu_x + \omega_x, \\ \omega_t = 2uu_{xxx} + 4u_x\omega + 4u\omega_x \end{cases}$$

for $u(x,t)$ and $\omega(x,t)$.

References

1. Inan I.E., Kilic B., Duran S. (G'/G) - expansion method and its applications to the 2-dimensional burgers equation and coupled burgers type equation.// World Applied Sciences Journal. – 2011. – Vol.12(10). – P.1883-1889.
2. Khater M.M.A. Soliton propagation under diffusive and nonlinear effects in physical systems; (1+1)–dimensional MNW integrable equation. // Physics Letters A. – 2023. – Vol. 480. – Id 128945.
3. Mingliang Wang, Xiangzheng Li, Jinliang Zhang. The (G'/G) - expansion method and travelling wave solutions of nonlinear evolution equations in mathematical physics. // Physics Letters A. – 2008. – Vol. 372(4). – P. 417-423.

OPTIMIZATION OF THE INVESTMENT PORTFOLIO

D. Kolesnikov, N. Semenova
Glushkov Institute of Cybernetics of NAS of Ukraine, Ukraine
danylokolesenikov@gmail.com, nvsemenova@meta.ua

Today's world of investment is very complex. It forces investors to look for new methods of optimizing their portfolios. The primary objective is to minimize overall risk while maintaining acceptable return potential. To achieve these goal investors needs to balance risk and return through mathematical modeling to create portfolios with the highest possible return for each level of risk. The problem of optimizing thes hare portfolio can be described in the following mathematical form:

$$W = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_{ij} \rightarrow min; \quad (1)$$

$$\sum_{i=1}^{n} w_i m_i \geq V_0 \quad (2)$$

$$\sum_{i=1}^{n} w_i = 1;\ w_i \geq 0; i = 1, \dots, n, \quad (3)$$

where w_i and w_j are the weights of investments in shares i and j;σ_{ij} is the covariance between the returns of shares i and j; σ_p^2 is the variance of the portfolio, V_0 is the desired level of profit. Harry Markowitz's portfolio optimization method maximizes expected return for a given level of risk by using an asset return matrix to assess interdependencies and overall portfolio risk. The key concept is the efficient frontier, which offers the best possible return for each level of risk, allowing investors to choose a portfolio according to their risk preferences and investment objectives. Portfolio optimization by the Markowitz method is performed by minimizing risks (1). By analytical method, the density of interconnection (correlation) of the initial indicators is investigated using the correlation coefficient, which, depending on the input data, can be calculated according to various formulas [2]. The covariance matrix is used to measure how returns on different assets vary together [2]. Mathematically, the covariance between assets i and $j$can be expressed by the formula:

$$\sigma_{ij} = \frac{1}{N-1} \sum_{t=1}^{N} (R_{it} - \bar{R}_i)(R_{jt} - \bar{R}_j) \quad (4)$$

where R_{it} ,R_{jt} are yields of assets i and j at time t, $\bar{R}_i$ and $\bar{R}_j$ are average yields of assets i and j, N is the total number of yield periods.

The proposed approach for optimizing the share portfolio is as follows:

1. Select a portfolio of shares for which optimization must be carried out. We define mandatory fields: ticker (share code), weight (share of shares in the investor's portfolio). For example, Amazon.com Inc

(AMZN): 30%, American Funds American Balanced A (ABALX): 25%, Dodge & Cox Stock I (DODGX): 20%, Energy Select Sector SPDR® ETF (XLE): 15%, Fidelity Contrafund (FCNTX): 10%.

2. Using historical price data [3], we calculate the covariance relations between portfolio assets using the covariance formula (4).

Table. 1. Covariance matrix

	AMZN	**DODGX**	**FCNTX**	**XLE**	**ABALX**
AMZN		0.0413	0.0511	0.0340	0.0267
DODGX	0.0413		0.0281	0.0438	0.0188
FCNTX	0.0511	0.0281		0.0343	0.0154
XLE	0.0340	0.0438	0.0343		0.0243
ABALX	0.0267	0.0188	0.0154	0.0243	

3. We optimize the stock portfolio according to the Markowitz method [1]. Choose the desired level of profitability. For example, let's define two different goals: 10% and 20% annual profitability.

Table. 2. Optimized portfolio

Ticker	**Assets weight with annual profitability 20% (%)**	**Assets weight with annual profitability 10% (%)**
AMZN	34.83	14.02
ABALX	28.19	3.81
XLE	5.65	0.00
FCNTX	31.32	82.17

The proposed stock optimization algorithm can be useful for investors who are interested in diversifying the risks of their portfolio and at the same time maintaining the desired level of profitability. He uses the method of H. Markowitz to optimize assets. With the help of the covariance matrix, the investor can easily optimize the stock portfolio and diversify it.

References

1. Hadetska S.V., Dubnytskyi V.Yu., Kushneruk Yu.I., Khodyrev O.I., Shkodina I.V. Multicriteria (vector) optimization of the currency portfolio in a non-stochastically uncertain external economic environment // Information processing systems. – 2021. – Vol. 3 (166). – P. 6–21. (in Ukrainian)

2. Humenyuk V.Ya., Mishchuk G.Yu., Oliynyk O.O. Risk management: Education. Manual. – Rivne: NUVHP, 2009 – 156 p.(in Ukrainian)

3. Morningstar Investor. URL: https://investor.morningstar.com(access date 06.03.2024)

A LAW OF THE ITERATED LOGARITHM FOR SMALL COUNTS IN KARLIN'S OCCUPANCY SCHEME

V. Kotelnikova, O. Iksanov
Taras Shevchenko National University of Kyiv, Ukraine
valeria.kotelnikova@unicyb.kiev.ua, iksan@univ.kiev.ua

In the Karlin infinite occupancy scheme, balls are thrown independently into an infinite array of boxes 1, 2, …, with probability p_k of hitting the box k. For $j, n \in \mathbb{N}$, denote by $\mathcal{K}_j^*(n)$ the number of boxes containing exactly j balls provided that n balls have been thrown. We call *small counts* the variables $\mathcal{K}_j^*(n)$, with j fixed.

Our main result is a law of the iterated logarithm (LIL) for the small counts as the number of balls thrown becomes large. Its proof exploits a Poissonization technique and is based on a new LIL for infinite sums of independent indicators $\sum_{k\geq 1} 1_{A_k(t)}$ as $t \to \infty$, where the family of events $(A_k(t))_{t\geq 0}$ is not necessarily monotone in t. The latter LIL is an extension of a LIL obtained recently by Buraczewski, Iksanov and Kotelnikova [1] in the situation that $(A_k(t))_{t\geq 0}$ forms a nondecreasing family of events.

The talk is based on the paper [2].

References

1. Buraczewski D., Iksanov A., Kotelnikova V. Limit theorems for sums of independent indicators, with applications to the Ginibre point process and Karlin's occupancy scheme // Preprint. – 2023. – Available at https://arxiv.org/abs/2306.15027.
2. Iksanov A., Kotelnikova V. A law of the iterated logarithm for small counts in Karlin's occupancy scheme. // Modern Stoch. Theory Appl. – 2024. – P. 1-29. DOI 10.15559/24-VMSTA248

RESILIENCE OF SYNCHRONIZATION MEANS OF ELECTRICAL NETWORKS AND TELECOMMUNICATION SYSTEMS UNDER THE CONDITIONS OF THE MILITARY STATE

V.V. Koval[1], V.P. Lysenko[1], O.V. Samkov[2], V.I. Vakas[3], I.Ya. Yanitskyi[4], O.M. Piskun[5], O.V. Kulesh[6]

[1]National University of Life and Environmental Sciences of Ukraine,
[2]Institute of Electrodynamics of the NAS of Ukraine,
[3]Private Joint Stock Company “Kyivstar”, Ukraine,
[4]Kyiv city branch of PJSC "Ukrtelecom", Ukraine,
[5]National space facilities control and test center, Ukraine
[6]Yuriy Fedkovych Chernivtsi National University, Ukraine
v.koval@nubip.edu.ua

In digital telecommunications, SMART and Micro power grids, synchronization tools are used to resolve time uncertainties. Synchronization tools that generate synchronization signals (SS) based on information received only from satellite navigation systems do not meet the requirements for resilience in martial law. The formation of SS with increased resilience is an urgent problem. The solution of which requires additional methods and technical means using computer-intensive technologies.

We propose an automated computer-integrated system for multichannel monitoring for synchronization signals that aggregates digital data from software and hardware from different manufacturers and provides prompt diagnostics of synchronization network status in normal operation and in emergency situations. The planning of placement of synchronization devices has been carried out considering geographical aspects, regional features, possible replacement of satellite radio navigation systems, and the use of a greater number of primary sources of synchronization.

To provide in the conditions of military state, the possibility of forming synchronization signals with standardized indicators and, accordingly, providing high-quality mobile communication services, have been implemented actions to reserve the synchronization network. The results of the analysis of the procedure for switching to reserve (other priority) in case of emergency situations are presented.

The computer-integrated system is a component for automated management of the technical operation on Ukrainian complex hybrid synchronization equipment.

EXTRAGRADIENT METHODS FOR VARIATIONAL INEQUALITIES WITH FUNCTIONAL CONSTRAINTS

O.Yu. Kovalenko[1], V.V. Semenov[1,2]
[1]Taras Shevchenko National University of Kyiv, Ukraine
[2]V.M. Glushkov Institute of Cybernetics of the NASU, Ukraine
{alexandra.kovalenko2000, semenov.volodya}@gmail.com

In this report proposed and investigated new algorithms for solving monotone variational inequalities with functional constraints.

Let H be a real Hilbert space. We consider the monotone variational inequality problem:

$$\text{find } x \in C : \langle Ax, y - x \rangle \geq 0 \quad \forall y \in C, \tag{1}$$

where $C \subseteq H$ is a closed convex set of and $A : H \to H$ is a monotone operator.

It is usually assumed that projection onto the set C is easy. Consider a problem where the admissible set C has the following form

$$C = X \cap \{x \in H : g_i(x) \leq 0, i = 1, ..., n\}, \tag{2}$$

where $C \subseteq H$ is a "projection-simple" closed convex set, and $g_i : H \to \mathbb{R}$ is a smooth convex functional for all i. Projection onto set (2) is not possible.

We see that problem (1), (2) is equivalent to problem:

$$\text{find } (x, \lambda) \in C \times \mathbb{R}^n_+ : \left.\begin{array}{l} \left\langle Ax + \sum_{i=1}^n \lambda_i \nabla g_i(x), y - x \right\rangle \geq 0 \ \forall y \in X, \\ \lambda_i g_i(x) = 0, \ \forall i = 1, ..., n. \end{array}\right\} \tag{3}$$

We can now apply an extragradient-type methods [1, 2] for problem (3).

References

1. Nemirovski A. Prox-method with rate of convergence O(1/T) for variational inequalities with Lipschitz continuous monotone operators and smooth convex-concave saddle point problems. // SIAM Journal on Optimization. – 2004. – Vol. 15. – P. 229-251.

2. Vedel Y., Semenov V., Denisov S. A Novel Algorithm with Self-adaptive Technique for Solving Variational Inequalities in Banach Spaces // in: Advances in Optimization and Applications, vol. 1514 of Communications in Computer and Information Science, Springer, Cham, 2021. – P. 50-64.

SYNTHESIS OF HYPERPLANE CLUSTER IN EUCLIDEAN SPACE

G.I. Kudin, T.P. Zinko
Taras Shevchenko National University of Kyiv, Ukraine
gkudin@ukr.net.ua

Solving various applied problems of digital information processing allows using the possibilities of the concept of pseudo inversion of matrices to create mathematical methods of information clustering and classification [1]-[4]. The use of elementary linear structures - hyperplanes - in Euclidean feature spaces provides not only the construction of effective algorithms for solving problems, but also the possibility of their optimization within the framework of their specific formulations. A variant of hyperplane clustering is associated with works [3], [4], in which the description of hyperplanes is carried out through hyperplanes, which are solutions (pseudo-solutions) of systems of linear algebraic equations (in this case, the problem of finding optimal elements of the basic matrix, vector of right parts.

Practically important tasks of image processing determine the task of operating objects with a matrix representation of information. The report proposes the method for constructing a hyperplane cluster for elements of the matrix Euclidean space.

References

1. Kirichenko N.F., Kudin G.I. Analysis and synthesis of signal classification systems by perturbing pseudoinverse and projection operations // Cybernetics and System Analysis. – 2009. – Vol. 45 (4). – P. 613-622.
2. Kirichenko N.F., Donchenko V.S. Pseudoinverse in clustering problems // Cybernetics and System Analysis. – 2007. – Vol. 43 (4). – P. 527-541.
3. Kirichenko N.F., Krivonos Yu.G., Lepekha N.P. Synthesis of systems of neurofunctional transformations in classification problems // Cybernetics and System Analysis. – 2008. – Vol. 44 (6). – P. 832-839.
4. Kudin G.I., Zinko T.P. Hyperplanes clusters in spaces of signs vectors // XXXII International Conference PROBLEMS OF DECISION MAKING UNDER UNCERTAINTIES, August 27-31, Prague, Czech Republic, 2018, p. 76-78.

CHOOSING OF OPTIMAL PORTFOLIO STRUCTURE

V. Kulian[1], M. Korobova[1], O. Yunkova[2]
[1] Taras Shevchenko National University of Kyiv, Ukraine
[2] Vadym Getman National Economy University of Kyiv, Ukraine
vkulian@knu.ua

When solving optimal control problem, we use the method of successive approximations. As a phase state we consider the market value of equity portfolio r_p and as the control parameters in accordance with the model - vector

$$u(t) = (x_i(t), r_i(t), \frac{dx_i(t)}{dt}, \frac{dr_i(t)}{dt}).$$

We consider a mathematical model of the dynamic formation of the market value of investment portfolio [1]; the desired level of the market value of the portfolio at the time T, $r_p(T) = r_P^T$; time interval $t \in [t_0, T]$; control constraints at each time point $x(t) \in U(t)$; quality criterion

$$J(x(t)) = \int_{t_0}^{T} (r_p(t) - r_p(T))^2 dt + \Phi(r_p(t_0)) \to \min_{x(t) \in U(t)}.$$

Here $\Phi(r_p(t_0))$ – given function. We need to identify $x(t_0)$ and, respectively, $r_p(t_0)$.

At the same time, we recall that the vector x describes the proportion of different types of shares in the portfolio, $x = (x_1, x_2, ..., x_n)$. Here n - number of shares in the investment portfolio types.

To solve the optimal control problem stated above with one fixed end of the trajectory and fixed time using the maximum principle.

References

1. Garashchenko F., Kulian V., Rutitskaya V. Quality analysis of mathematical models of investment management // Cybernetics and computing engineering. – 2015. – Vol. 148. – P. 3-10.

REGULARIZATION OF VECTOR MIXED INTEGER OPTIMIZATION PROBLEM

T.T. Lebedeva, N.V. Semenova, T.I. Sergienko
Glushkov Institute of Cybernetics of NAS of Ukraine
nvsemenova@meta.ua, lebedevatt@gmail.com, taniaser62@gmail.com

The existence of unstable vector problems is due to the need to create a regular operator, which is a specific type of perturbation of the input data of the problem with the replacement of a possibly unstable problem with a series of stable perturbed ones. New results have been obtained related to regularization of vector optimization problems under possible perturbations of input data of a vector criterion. In the case of Pareto optimization, an approach to regularization of problems with quadratic criterion functions has been developed. Let's consider the vector optimization problem $Z(F_u, X)$: $\max\{F(x) \mid x \in X\}$, where $F(x) = (f_1(x),..., f_\ell(x))$, $\ell \geq 2$, $X \neq \varnothing$, X – set of arbitrary structure, possibly partially discrete, $X \subset R^n$, $f_i(x) = \langle x, D_i x\rangle + \langle c_i, x\rangle$, $c_i \in R^n$, $D_i \in R^{n\times n}$, $i \in N_\ell = \{1,...,\ell\}$. $Sl(F, X)$ and $P(F, X)$ are sets of optimal solutions of the problem $Z(F_u, X)$. For a set of input data $u \in U$ and $\forall \delta > 0$ define a set of perturbed input data $O_\delta(u) = \{u(\delta) \in U \mid \|u(\delta) - u\| < \delta\}$. Problem $Z(F_{u(\delta)}, X)$ is $\max\{F_{u(\delta)}(x) \mid x \in X\}$, where $u(\delta) \in O_\delta(u)$, $F_{u(\delta)}(x) = (f_1^{u(\delta)}(x),..., f_\ell^{u(\delta)}(x))$.

Definition 1. The problem $Z_{Sl}(F_u, X)$ ($Z_P(F_u, X)$) will be considered stable according to the vector criterion if $\forall \varepsilon > 0$ $\exists \delta > 0$: $\forall u(\delta) \in O_\delta(u)$ the condition $Sl(F_{u(\delta)}, X) \subset O_\varepsilon(Sl(F_u, X))$ ($P(F_{u(\delta)}, X) \subset O_\varepsilon(P(F_u, X))$, where $O_\varepsilon(B) = \left\{x \in R^n \mid \inf_{y\in B} \|x - y\| < \varepsilon\right\}$.

Theorem 1. [2]. If the feasible set X of the problem $Z(F_u, X)$, where $u \in U$, is compact, then $\forall \varepsilon > 0$ $\exists \delta > 0$ such that $\forall u(\delta) \in O_\delta(u)$: $Sl\left(F_{u(\delta)}, X\right) \subset O_\varepsilon Sl\left(F_u, X\right)$.

Sufficient conditions for the stability of the problem $Z_P(F_u, X)$, where $u \in U$, for finding Pareto-optimal solutions are formulated in the Theorem 2 and proved in [1].

Theorem 2. If an feasible set X is compact and, in addition, equality holds $S\ell(F_u, X) = \mathrm{cl}(P(F_u, X))$, where $\mathrm{cl}B$ is the closure of any set $B \subset R^n$, then the problem $Z_P(F_u, X)$, where $u \in U$, is stable by the vector criterion.

The approach to the regularization of the problem $Z_P(F_u, X)$ with quadratic criterion has been developed and substantiated.

Let's perturb the vector criterion in a certain way. $F_{u^\tau}(x) = \left\{ f^1_{u^\tau}(x), .., f^\ell_{u^\tau}(x) \right\}$, where $u^\tau = (D^\tau, C^\tau) \in U$,

$f^i_{u^\tau}(x) = \left\langle x, D^\tau_i x \right\rangle + \left\langle c^\tau_i, x \right\rangle$, $C^\tau \in R^{\ell \times n}$, $D^\tau_i = D_i - \tau \sum_{k \in N_\ell} \mu_k D_k$,

$c^\tau_i = c_i - \tau \sum_{k \in N_\ell} \mu_k c_k$, $D^\tau_i \in R^{n \times n}$, $\mu_i > 0$, $i \in N_\ell$.

Theorem 3. [3]. Let the set feasible X is compact. Then $\forall \tau < 0$, $\forall \varepsilon > 0 \quad \exists \delta > 0$ also such that there $\forall u^\tau(\delta) \in O_\delta(u^\tau)$ is a place of inclusion $S\ell(F_{u^\tau(\delta)}, X) \subset O_\varepsilon P(F_u, X)$.

References

1. Lebedeva T.T., Semenova N.V., Sergienko T.I. Stability and regularization of vector optimization problems under possible criteria disturbances. // Cybernetics and Systems Analysis. – 2022. – Vol. 58(5). – P. 721–726.

2. Lebedeva T.T., Semenova N.V., Sergienko T.I. Multi-objective optimization problem: stability against perturbations of input data in vector-valued criterion. // Cybernetics and Systems Analysis. – 2020. – Vol. 56(6). – P. 953–958. https://doi.org/10.1007/s10559-020-00315-9.

3. Lebedeva T.T., Semenova N.V., Sergienko T.I. Regularization of the vector problems with quadratic criteria of Pareto optimization. // Cybernetic and Systems analysis. – 2023. – Vol.59(4). – P. 561–566.

STRUCTURE OF OPTIMAL SADDLE-NODE BIFURCATIONS ON THE TORUS WITH A HOLE

Taras Shevchenko National University of Kyiv, Ukraine
Maria Loseva, Alexandr Prishlyak

We describe all possible topological structures of Morse flows and typical gradient saddle-node bifurcation of flows on the 2-dimensional torus with a hole in the case that the number of singular points of flows is at most six. To describe structures, we use separatrix diagrams of flows. The saddle-node bifurcation is specified by selecting a separatrix in the separatrix diagram of the flow before the bifurcation.

A Morse flow is a gradient flow of Morse function. The flow has no cycles and polycycles. In typical one-parameter families of gradient flows, two types of bifurcations are possible: saddle-node and saddle connection. The corresponding vector fields at the time of the bifurcation are fields of codimension 1. In our case, they completely determine the topological type of the bifurcation. To classify Morse flows, a separatrix diagram is used, in which separatrices are trajectories that belong to one-dimensional stable or unstable manifolds. We apply this approach to the classification of typical saddle-node bifurcation.

Morse flows satisfy three properties: 1) singular points are nondegenerate; 2) there are no separatrix connections in the interior; 3) α-limiting (ω-limiting) set of a trajectory is a singular point.

There are three types of singular points for Morse flow on 2-manifolds: 1) a source, 2) a saddle, 3) a sink.

The following types of bifurcations are possible:

SN – separatrix, between internal points, one of which is a saddle,

BSN – trajectory on the boundary, between points, one of which is a saddle,

HN – separatrix between the saddle on the boundary and the internal point,

HS – separatrix between the inner saddle and a point on the boundary,

BDS – a trajectory on the border, between two saddles.

Number of points	Morse	SN	BSN	BDS	HN	HS
4	1	0	0	0	0	0
5	3	0	2	1	2	0
6	21	20	14	10	4	26

Table 1 – Number of Morse flows and bifurcations on the torus with a hole

An optimal bifurcation is a bifurcation that has the smallest number of singular points among bifurcations of its type. In accordance with the calculations obtained, which are shown in Table 1, the following occurs:

Theorem. For a torus with a hole, there are 20 bifurcation structures of type SN, 2 of type BSN, 1 of type BDs, 2 of type HN, and 26 of type HS.

References

1. S. Bilun, M. Loseva, O. Myshnova, A. Prishlyak. Typical one-parameter bifurcations of gradient flows with at most six singular points on the 2-sphere with holes. // arXiv preprint arXiv:2303.14975, 2023. doi:10.48550/arXiv.2303.14975

2. M. Loseva, A. Prishlyak, K. Semenovych, D. Synieok Structure of Morse flows with at most six singular points on the torus with a hole. // arXiv preprint arXiv:2404.02223, 2024.doi:10.48550/arXiv.2404.02223

3. B.Hladysh, M.Loseva, A. Prishlyak. Topological structure of functions with isolated critical points on a 3-manifold. // Proceedings of the International Geometry Center. – 2023. – Vol. 16(3). – P.231-243. doi:10.15673/ pigc.v16i3.2512 .

4. M. Losieva, A. Prishlyak. Topology of Morse-Smale flows with singularities on the boundary of a two-dimensional disk. // Proceedings of the International Geometry Center. – 2016. – Vol. 9(2). – P.32-41. doi:10.15673/tmgc.v9i2.279 .

5. A. Prishlyak, M. Loseva. Topology of optimal flows with collective dynamics on closed orientable surfaces. // Proceedings of the International Geometry Center. – 2020. – Vol. 13(2). – P.50-67. doi:10.15673/tmgc. v13i2.1731.

6. A.O. Prishlyak, M.V. Loseva. Optimal Morse-Smale flows with singularities on the boundary of a surface. //Journal of Mathematical Sciences. – 2019. – Vol.243. – P.279-286.

DEVELOPMENT AND IMPLEMENTATION OF A LARGE LANGUAGE MODEL ASSISTANT FOR MITIGATING COGNITIVE BIASES IN GROUP DECISION-MAKING

Andrii Luzan
V.M. Glushkov Institute of Cybernetics of the NASU, Ukraine
aluzan@kse.org.ua

Effective decision-making under uncertainty is a significant challenge for organizations, often hampered by cognitive biases like confirmation bias, anchoring, and groupthink. This paper presents a Large Language Model (LLM) assistant designed to enhance group meetings by reducing these biases and improving decision-making quality through advanced natural language processing and real-time feedback.

Trained on diverse datasets, the LLM assistant detects biases and proposes corrective actions. Testing in simulated environments shows its effectiveness in promoting critical thinking and diverse viewpoints, resulting in better decisions and increased participant satisfaction. Seamless integration into virtual meeting platforms ensures workflow continuity.

A monitoring framework ensures continuous improvement, including real-time performance tracking, user feedback, evaluation reports, and adaptive learning. Ethical and privacy considerations are prioritized to ensure compliance with standards and protect participant confidentiality.

This research provides a practical solution for organizations to mitigate cognitive biases in group decision-making, contributing to decision science and enhancing decision processes under uncertainty.

ABOUT STEADY STATE DISTRIBUTION FOR RETRIAL QUEUES WITH HYSTERESIS STRATEGIES

I. Makushenko, I. Usar
Taras Shevchenko National University of Kyiv, Ukraine
iamak@ukr.net

We deal with a retrial queues of the type $M/M/m$, $m=1,2$ in which a rate of primary calls depends on the number of customers in the orbit [1]. The rates of repeated calls and of the service process are supposed to be constant. Variable character of the input flow rate allows to consider

the system under different strategies. In the report we consider the hysteresis strategies which means that there are two different levels, say h_1 and h_2, $0 < h_1 \le h_2$ and two regimes for the input flow. The first regime means that the input flow has a rate $\lambda_1(j)$ while the second one means that a rate is equal to $\lambda_2(j)$. The system operates in the following way. Let $\xi(t)$ be the number of customers in the orbit at the time t and $0 \le \xi(0) < h_2$. If $t < \tau(h_2) = \inf\{t : \xi(t) = h_2\}$ the system follows the first regime. At the time $\tau(h_2)$ the input flow starts to follow the second regime. That regime remains till the number of customers in the orbit reaches the level h_1 at which time a rate of the input flow becomes $\lambda_1(j)$ again. The explicit formulae for steady state distribution of the customers in the system are obtained which enables to propose an effective solving algorithm for optimization problems consisting in finding optimal positions for the levels h_1, h_2 to maximize some objective function. As such a function we took the following one (all characteristics below are considered in steady state regime)

$$W(h_1, h_2) = C_1 S_1(h_1, h_2) - C_2 S_2(h_1, h_2) - C_3 S_3(h_1, h_2),$$

where $S_1(h_1, h_2)$ - the number of calls have being served; $S_2(h_1, h_2)$ - the number of calls that become repeated calls; $S_3(h_1, h_2)$ - the number of switching of the input flow; C_1 - profit associated with service of a call; C_2 - penalty for refusal to serve; C_3 - penalty for switching of the input flow rate.

References

1. Makushenko I., Livinska H., Usar I., Sharapov M. Optimal threshold strategies for retrial systems with queue. // Journal of Computational and Applied Mathematics. – 2023. – Vol. 427. – P. 115 - 136.

STUDY ON THE OPERATIONAL STABILITY OF A LACTATE BIOSENSOR: MODELING, PARAMETER IDENTIFICATION AND STABILITY EVALUATION

V. Martsenyuk[1], O. Soldatkin[2], A. Kłos-Witkowska[1], A. Sverstiuk[3,4], K. Berketa[2]

[1]University of Bielsko-Biala, Poland

[2]Institute of Molecular Biology and Genetics of NASU, Ukraine

[3]Ivan Horbachevsky Ternopil National Medical University, Ukraine

[4]Ternopil Ivan Puluj National Technical University, Ukraine

vmartsenyuk@ubb.edu.pl, alex_sold@yahoo.com, aklos@ubb.edu.pl, sverstyuk@tdmu.edu.ua, ksenya.berketa.10@gmail.com

The study focuses on the operational stability of a lactate biosensor. It encompasses modelling the biosensor's behaviour, identifying key parameters that affect its performance, and analysing its stability over time. The research aims to enhance the reliability and accuracy of lactate measurements by addressing potential issues in sensor stability and optimizing its design and functionality.

Lactate, an end product of anaerobic glucose metabolism, is vital in medicine as a marker for conditions like hypoxia, diabetes, and liver and kidney diseases. It's also used in the food industry as an emulsifier, thickener, and acidity regulator, and to monitor fermentation. Traditional lactate measurement methods, while effective, are often costly and complex. Biosensors provide a faster, more affordable, and simpler alternative, using either lactate oxidase (LOx) or lactate dehydrogenase (LHD). Mixed-enzyme biosensors offer higher sensitivity but are more expensive and complex.

Despite advancements, many biosensors lack readiness for commercialization due to limitations in sensitivity and selectivity. Mathematical modeling is essential for developing new biosensors to ensure cost-effectiveness and reliability. Stability analysis of biosensors, using techniques like linearization and Lyapunov functions, is crucial for their performance in medical and industrial applications.

Materials used in the study included lactate oxidase enzyme from Aerococcus viridans, bovine serum albumin (BSA), glutaraldehyde (GA), glycerol, KCl, and sodium L-lactate solution. These were sourced from Sigma-Aldrich and other suppliers. Aerometric transducers were platinum disc electrodes fabricated in-house. The setup for aerometric measurements included a PalmSens potentiostat connected to platinum and silver chloride reference electrodes, as well as working electrodes based on platinum discs. A CH-8 multiplexer facilitated signal reception from multiple electrodes simultaneously. Proteins were immobilized on platinum electrodes using glutaraldehyde to create bioselective membranes. Aerometric measurements were conducted in a 2 ml open cell with constant stirring, applying a potential of +0.6 V. The buffer used was 25 mM HEPES with pH 7.4, and substrate concentration was adjusted with standard sodium L-lactate solution. Each measurement cycle took 4-5 minutes, with the biosensor washed between cycles

In this study, equilibrium conditions of the system were examined, showing that in the absence of substrate and complex, and with enzyme concentration equal to the total available enzyme, the system reaches equilibrium. The product concentration remains constant, determined by the initial substrate concentration. Additionally, a model with two discrete delays was considered, where $\tau 1$ and $\tau 2$ represent the time durations for substrate binding and complex breakdown, respectively. Increasing these parameters was found to destabilize the system, affecting enzyme and product levels, and thus the biosensor index. The study highlights the dynamic nature of enzyme kinetics, with reaction rates depending on substance concentrations. Experimental validation is needed, and the models could be expanded to include other complexes involving biosensor components like BSA.

These findings offer insights into system dynamics and stress the importance of parameter exploration in enzyme kinetics models [1].

References

1. Martsenyuk V., Soldatkin O., Kłos-Witkowska A., Sverstiuk A., Berketa K. Operational Stability Study of Lactate Biosensor: Modeling, Parameter Identification, and Stability Analysis. // Bioeng. Biotechnol. Sec. Biosensors and Biomolecular Electronics. – 2024. – Vol.12. doi: 10.3389/fbioe.2024.1385459

ON AGGREGATION OF EXPERT ASSESSMENTS FOR A FUZZY SET OF DECISION-MAKERS

S.O. Mashchenko
Taras Shevchenko National University of Kyiv, Ukraine
s.o.mashchenko@gmail.com

Let $N = \{1,...,n\}$ be a set of experts. Each expert $i \in N$ provides the assessment $a_i \in \mathbb{R}$. We consider the question: 'What is the value of the ordered weighted averaging (OWA) operator in the case when the set of experts is fuzzy?' In other words, what do we obtain if we use the OWA operator if the importance of the expert $i \in N$ is determined by the membership degree $\mu_{\tilde{N}}(i)$ of the FS $\tilde{N} = \{(i, \mu_{\tilde{N}}(i)) : i \in N\}$?

According to the proposed approach, the OWA value for a fuzzy set of experts is a type-2 fuzzy set (T2FS) on the real line, decomposed into a collection of embedded T2FSs with constant secondary grades. Such sets are quite simple for practical use, in contrast to T2FSs of a general form [1]. To present the T2FS aggregated value in a form that is easy to understand and interpretate, we used a decomposition approach. The results obtained allow us to decompose the value T2FS of the OWA operator according to secondary grades into a finite collection of numbers with corresponding degrees of truths. These numbers are OWA values corresponding to different cuts of the fuzzy set of experts. Thus, the proposed approach makes it possible to determine several aggregated values of the OWA operator for a given collection of expert assessments, depending on the required degree of truth. Future research direction may be related to the development of a similar approach for group decision-making problems with fuzzy assessments. The author hope that the proposed approach not only expands the scope of application of a group decision-making to the case of fuzzy set of experts, but can also provide new approaches to solving other formulations of fuzzy decision-making problems.

References

1. MASHCHENKO, S. (2018) Sums of fuzzy set of summands. *Fuzzy Sets Syst.* 417. pp. 140–151.
2. MASHCHENKO, S. (2021) Sum of discrete fuzzy numbers with fuzzy set of summands. *Cybernetics and Systems Analysis*. 57(3). pp. 374–382.

DECISION-MAKING IN THE MANAGEMENT OF HIGHER EDUCATION INSTITUTIONS IN FUZZY CONDITIONS

K. Merkulova, I. Lybak
Taras Shevchenko National University of Kyiv, Ukraine,
k.merkulova@knu.ua, iryna.lybak@rshu.edu.ua

In modern conditions of uncertainty, questions and problems of decision-making and analysis of complex systems are becoming more and more relevant. The management system of higher education institutions is based on decision-making. The information environment for decision-making by the Higher Education Institution is unclear, that is, it includes judgments, considerations, and expert assessments. For effective decision-making in such an environment, standard mathematical models and logical schemes are not suitable, special methods and tools are required. In global practice, an approach based on the theory of fuzzy sets by L. Zade [1] is successfully used to solve such problems. The construction of models that are close to human reasoning and their use will be an effective solution for the management of higher education institutions. The decision-making process in fuzzy conditions, when goals and constraints are set by a fuzzy set, was considered in the work of Bellman and Zadeh [2]. Making a decision is choosing an alternative that satisfies both fuzzy goals and fuzzy constraints. When making a decision according to the Bellman-Zade scheme, the main thing is that the decision criteria and the set of alternatives are considered as equal fuzzy subsets of a certain universal set of alternatives. This makes it possible to determine the solution of the problem in a rather simple form [3].

References

1. Zadeh L. Fuzzy Sets// Information and Control. –1965. — Vol.8. — P. 338—353.
2. R. E. Bellman, L. A. Zadeh, (1970) Decision-Making in a Fuzzy Environment. Management Science 17(4): B-141-B-164.
3. V.K. Anikin Theory of decision-making: education. manual / V.K. Anikin, E.V. Krylov, V.P. Pasko; Ministry of Education and Science of Ukraine, KPI named after I. Sikorskyi. - Kyiv, - 2023. - 134 p.

COMPUTER INTENSIVE TECHNIQUES FOR DECISION MAKING IN DIFFERENT FIELDS

K. Merkulova, V. Spitsyn
Taras Shevchenko National University of Kyiv, Ukraine,
k.merkulova@knu.ua; vspitsyn@knu.ua

Computer-intensive techniques are crucial in modern business and research, enabling data processing and decision automation with high accuracy and efficiency. This thesis examines these techniques and their applications, particularly for corporate email security.

Key Techniques and Applications

Data Analysis and Visualization Software like Excel, R, and Python process large data volumes, identify trends, and use charts and diagrams for better decision-making [1].

Process Automation Scripts and macros automate routine tasks, reducing errors. In corporate email, this includes automatic sorting, detection, and encryption of sensitive information before sending emails externally [2].

Database Management Systems (DBMS) DBMSs like MySQL, PostgreSQL, and MongoDB store and manage large data volumes. In your coursework, DBMSs can store dictionaries of sensitive words and phrases for detection and encryption [3].

Computer-intensive techniques enhance decision-making accuracy, efficiency, and security. Using data analysis, automation, and DBMS improves the protection of sensitive information in corporate email, aligning with your coursework goals.

References

1. Data Analysis and Visualization Techniques, ScienceDirect. [Internet source] – https://www.sciencedirect.com/
2. Automation in Email Management, TechTarget. [Internet source] – https://www.techtarget.com/
3. Database Management Systems, Database Journal. [Internet source] – https://www.databasejournal.com/

INVERSE PROBLEMS FOR THE EQUATIONS OF A WEAKLY COMPRESSIBLE FLUID UNDER CONDITIONS OF UNCERTAINTY

O. Nakonechnyi, D. Cherniy, I. Dyyak
Taras Shevchenko National University of Kyiv, Ukraine
dmytro.cherniy@knu.ua

Let Ω and Ω_j – j be bounded regions in the space $\mathbb{R}^n$ with piecewise smooth boundaries Γ and Γ_j, $\Omega_J \subseteq \Omega$ and $\Omega_j \cap \Omega_k = \varnothing$, $k \neq j$. Let the vector of functions be given

$$y_k = C_k(x)\phi + v_k(x), \quad x \in \Omega_k, \quad k = \overline{1,N},$$

where vector function $\phi(x) = \left(\phi_1(x),\ldots,\phi_n(x)\right)^T$ is also a solution of the Lipschitz equation for a weakly compressible fluid

$$L\phi = -\nu\Delta\phi - \varepsilon^{-1} grad\, div\phi = f(x),\ x \in \Omega,\ \phi\big|_{\Gamma} = 0,$$

where Δ is the Laplace operator, $C_k(x)$ is matrix function whose elements are continuous in $\overline{\Omega}$, $C_k(x): \mathbb{R}^n \to \mathbb{R}^s$.

Functions $f(x)$ and $\left(v_1(x),\ldots,v_N(x)\right)^T = v(x)$ are unknown and belong to the bounded multiple of functions integrated with the square.

We denote by $\mathcal{L}$ the set of mixed estimates of the function $f(x)$ based on the data $y_k(x)$, $k = \overline{1,N}$, of the form

$$\hat{f}(x) = \sum\nolimits_{k=1}^{N} \int_{\Omega_k} U_k(x,x_1) y_k(x_1) dx_1 + d(x),$$

where $U_k(x,x_1)$ are matrix functions integrated with the square on Ω_k; $d(x)$ is function integrated with the square on Ω. We will find the guaranteed lower and upper estimates for the function $f(x)$ from the conditions

$$\left(u^{(i)}, d^{(i)}\right) \in Argmin\, \delta_i(u,d),$$

where

$$\delta_i^2(u,d) = \max_{(f,v)\in G_i} \int_{\Omega} \left| f(x) - \hat{f}(x) \right|^2 dx,$$

$$G_i = \Big\{ (f, v) : \int_\Omega Q_0^{(i)} \big(f(x) - f_0(x), f(x) - f_0(x) \big) dx + \\ + \sum_{k=1}^{N} \int_{\Omega_k} \Big(Q_k^{(i)} v_k(x), v_k(x) \Big) dx \le 1 \Big\},$$

$Q_k^{(i)}$, $k = \overline{0, N}$ are positive-valued matrices, $f_0(x)$ are known functions integrated with the square. Then the assertion takes place:

Assertion. The lower and upper bounds of the estimate $\hat{f}^{(i)}(x)$ of the function $f(x)$ have the form

$$\hat{f}^{(i)}(x) = Q_0^{(i)} p^{(i)}(x),$$

where the function $\left(p^{(i)}(x), \phi^{(i)}(x) \right)$ are generalized solutions of the system of equations:

$$\begin{cases} L\, p^{(i)} = \sum_{k=1}^{N} C_k^T(x) Q_k^{(i)} \left(y_k(x) - \phi^{(i)}(x) \right) \chi_{\Omega_k}(x), \\ L\, \phi^{(i)} = Q_0^{(i)} p^{(i)}(x), \quad p^{(i)} \big|_\Gamma = \phi^{(i)} \big|_\Gamma = 0. \end{cases}$$

Estimates for the errors of the guaranteed estimates are also obtained.

References

1. Nakonechnyi O.H. Optimal control and estimation in partial differential equations. – Kyiv University Publishing House, 2004. – 103 p.

ON BALLEANS DYNAMICS UNDER FUZZY CONDITIONS

O.G. Nakonechnyi, S.O. Mashchenko
Taras Shevchenko National University of Kyiv, Ukraine
a.nakonechniy@gmail.com, s.o.mashchenko@gmail.com

Let $\mathrm{B} = 2^\Omega$ be the set of all subsets of some set Ω. The following problems are investigated in the report.

Problem 1. We denote by $F_t : \mathrm{B} \to \mathrm{B}$ a crisp mapping on B such that takes the values also on B for each $t \in \{0, ..., T\}$. Denote X_0 the fuzzy set on Ω with the membership function $\mu_{X_0}(x)$, $x \in \Omega$. We found the fuzzy set X_T under condition

$$X_{t+1} = F_t(X_t), \; t \in \{0, ..., T\}. \qquad (1)$$

Problem 2. We denote by $\tilde{F}_t : \mathrm{B} \times \mathrm{B} \to [0,1]$ a fuzzy mapping on B

such that takes the values also on B for each $t \in \{0,...,T\}$ with the membership function $\mu_{\tilde{F}_t}(x,y)$, $x,y \in \Omega$. We found the fuzzy set $\hat{X}_T$ under condition

$$X_{t+1} = \tilde{F}_t(X_t),\ t \in \{0,...,T\}. \quad (2)$$

Problem 3. Denote by $\tilde{T}$ a fuzzy number with the membership function $\mu_{\tilde{T}}(r)$, $r \in \mathbb{R}$, where $\mathbb{R}$ is the real line. We found the fuzzy set $X_{\tilde{T}}$ under condition

$$X_{t+1} = \tilde{F}_t(X_t),\ t \in \{0,...,\tilde{T}\}. \quad (3)$$

Acknowledgements. This work was supported by the Ministry of Education and Science of Ukraine within the framework of project № 22BF015-02 (state registration number 0122U001844) at Taras Shevchenko National University of Kyiv.

References

1. Nakonechnyi O.H., Grebennik I.V., Romanova T.Ie., Teviashev A.D. Methods of Decision Making. - Kharkiv: ХНУРЕ, 2016. – 131 с. (in Ukranian)

2. Protasov I. Selectors and orderings of coarse spaces. // Ukrain. Math. Bull. – 2021. – Vol. 18. – P. 70–78.

ESTIMATION METHODS IN OBSERVATION PROBLEMS UNDER CONDITIONS OF UNCERTAINTY

O. Nakonechnyi, P. Zinko, M. Hnatyshko
Taras Shevchenko National University of Kyiv, Ukraine
maksimgnatisko@gmail.com

The observation problem is an integral part of many areas. In general, the problem of observation means making accurate and meaningful observations or measurements in a given discipline or field. The purposes and tasks of the work is to show that the estimation methods can be applied to solve the economic tasks, namely, to determine the solution of the inter-industry balance equation under conditions of uncertainty.

The model considered in this work is Leontief's model, also known as the input-output model. Consider n industries that produce n different products.

Let $x = (x_1,\ x_2,\ \dots,\ x_n)^T$ be a vector of the total produced volume, $b = (b_1,\ b_2,\ \dots,\ b_n)^T$ be a vector of final consumption and

$T = \{t_{ij}\}_1^n,\ i,j = \overline{1,\ n}$ - $n \times n$ technological matrix (matrix of coefficients of direct production cost). Then the Leontief's model of inter-industry balance can be written as a matrix equation:

$$x = Tx + b, x \geq 0,$$

or we can rewrite it as:

$$(E - T)x = b, \quad (1)$$

where E - $n \times n$ unit matrix.

The method used in this work is the method of estimation of operator equations solutions under conditions of uncertainty described in [1]. Let matrix X be a solution of the operator equation of the form:

$$A(\omega)X = \sum_{i=1}^{p} B_i \xi_i + A^{(0)}, \quad (2)$$

where $X \in H_{n\times m}$, $H_{n\times m}$ is the space of $n \times m$ dimension matrices; $A(\omega)$ – is a random linear operator that acts from space $H_{n\times m}$ to space $H_{n\times m}$, the distribution of $A(\omega)$ is given; $B_i,\ i = \overline{1,p}$ are given matrices from $H_{n\times m}$; $\xi_i, i = \overline{1,p}$ are random scalar variables; $A^{(0)}$ is given matrix from $H_{n\times m}$.

Assume that the observations of the matrix X are given and has the form:

$$y_k = SpXC_k^T + \eta_k, k = \overline{1,N}, \quad (3)$$

where $C_k \in H_{n\times m},\ k = \overline{1,\ N}$ – given matrices, N – number of observations, $Sp(W)$ – trace of square matrix, η_k are implementation of random variables, $E\eta_k = 0,\ k = \overline{1,\ N},\ R_\xi \in G_1,\ R_\eta \in G_2$ – correlation matrices of ξ and η respectively. Consider the case, when the linear operator L is given in the form: $LX = \langle L, X\rangle,\ L \in H_{n\times m}$

Let's describe an algorithm for finding the estimation of LX.

Algorithm 1:

- Define matrices L, $A^{(0)}$, B_i, C_k, $i = \overline{1,\ p}$, $k = \overline{1,\ N}$ and operator $A(\omega)$;
- Find EP and $E\psi$ – the mathematical expectations of the solutions of the systems of equations:

$$\begin{cases} A^*(\omega)\psi = L - \rho(C)\hat{u} \\ A(\omega)P = (\rho(B)R_\xi\rho^*(B) + A^{(0)} \otimes A^{(0)})\psi, \end{cases}$$

where $\rho(.)$ is operator that acts from vector space to matrix space according to the rule: $\rho(M)x = \sum_{i=1}^{s} M_i x_i,\ x = (x_1, \dots, x_s)^T,\ M_i, i = \overline{1,\ s}$ – the sequence of matrices

- Calculate $\hat{u}$ and $\hat{\alpha}$ using formulas:

$$\hat{u} = R_\eta^+ \rho^*(C)\left(EP + \bar{A}A^{(0)}\left\langle E\psi, A^{(0)}\right\rangle\right), \quad \hat{\alpha} = \left\langle E\psi, A^{(0)}\right\rangle,$$

- Calculate the root-mean square estimation of $\langle L, X\rangle$ using formula:

$$\overline{\overline{\langle L, X\rangle}} = (\hat{u}, y) + \hat{\alpha}.$$

Let E_s, $s = 1,2, \ldots$ be the basis matrices in the matrix space $H_{n\times m}$ such that $\langle E_s, E_p \rangle = \begin{cases} 1, \ if \ s = p, \\ 0, \ if \ s \neq p, \end{cases}$. Let $\overline{\overline{\langle E_s, X \rangle}}$ denote the root-mean square estimate of the scalar product $\langle E_s, X \rangle$. Then by root-mean square estimate of the matrix X we mean the following expression:

$$\bar{\bar{X}} = \sum_s \overline{\overline{\langle E_s, X \rangle}} \, E_s.$$

Consider the inter-industry balance equation under conditions of uncertainty. By this we mean that the technological matrix and the matrix of final consumption are random, the intervals on which their elements are located and kind of their distribution are given. To estimate the solution of the inter-industry balance equation (1) we have to define the equation (2) in propriate form. Define operator $A(\omega)$ in the following way:

$$A(\omega)X = (E - T)X$$

Redefine matrices B_i as matrices B_{ij} and $A^{(0)}$ as follows:

$$\begin{cases} B_{ij} = \left\{d_{sq}\right\}_{q=\overline{1,m}}^{s=\overline{1,n}}, \\ d_{sq} = \begin{cases} \dfrac{|b_{ij}^- - \ b_{ij}^+|}{2}, \ if \ s = i \ and \ q = j \\ 0, \ otherwise \end{cases} ; \ i, s = \overline{1,n}; \ j, q = \overline{1,m}, \\ A^{(0)} = \{\dfrac{b_{ij}^- + \ b_{ij}^+}{2}\}_{j=\overline{1,m}}^{i=\overline{1,n}}. \end{cases}$$

The validity of results was shown on example. We are considering the system of two industries. Assume that the technological matrix is a uniformly distributed random matrix The elements of technological matrix are uniformly distributed random quantities on intervals $[t_{ij}^-, t_{ij}^+]$, $i, j = \overline{1,2}$ that are given as element of the following matrix:

$$\{[t_{ij}^-, t_{ij}^+]\}_{j=\overline{1,2}}^{i=\overline{1,2}} = \begin{bmatrix} [0, \ 0] & [2.5, \ 2.8] \\ [0.1, \ 0.15] & [0, \ 0] \end{bmatrix}$$

The same way intervals for elements of matrix of final consumption are given: $\{[b_i^-, b_i^+]\}_{i=\overline{1,2}} = [[10, 11] \, [100, 100]]^T$. In general, our formulation let technological matrix and matrix of final consumption be random matrices with any distributions. Figure 1 represents the plot of relative error of estimation depending on the number of observations for both components of vector X.

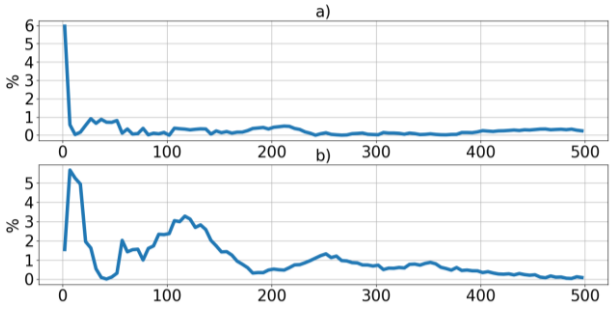

Figure 1

As we can see from the plot, the error decreases when the number of observations increases.

References

1. Nakonechnyi O.G., Zinko P.M. Estimates of matrix solutions of operator equations with random parameters under uncertainties. // Matematychni Studii. – 2023. – Vol.60(2). – P. 208-222.

2. Nakonechniy O.G., Kudin G.I., Zinko P.M., Zinko T.P., Shusharin Y.V. Guaranteed root mean square estimates of linear matrix equations solutions under conditions of uncertainty // Mathematical Modeling and Computing. – 2023. – Vol.102.– P. 474 – 486.

3. Nakonechniy O.G., Kudin G.I., Zinko P.M., Zinko T.P. Guaranteed root mean square estimates of observations with unknown matrices // Journal of Numerical and Applied Mathematics. – 2022. – Vol.2. – P. 98-115. (in Ukrainian)

GUARANTEED A POSTERIORI ESTIMATES OF THE SOLUTIONS OF THE OPERATOR EQUATIONS AND THEIR ERRORS

O. Nakonechniy, P. Zinko, T. Zinko

Taras Shevchenko National University of Kyiv, Ukraine

a.nakonechniy@gmail.com, petro.zinko@knu.ua, taras.zinko@knu.ua

Many publications by foreign scientists, in particular [1-3], are devoted to the problems of applying matrix theory in statistics, machine learning, biology, engineering, and evaluation of matrices and vectors in large-dimensional models based on observational data. In the works of the authors [4-6], problems of linear matrix regression under conditions of uncertainty were studied, in [7-9] guaranteed estimates of matrices,

which are solutions of operator equations, were found based on observations of a special form. In these works, it was assumed that equations whose solutions are observed with errors have a unique solution. This report contains guaranteed a posteriori estimates for rectangular matrices, which are solutions of linear operator equations with unknown right-hand sides, as well as obtained expressions for upper and lower estimates of solutions of such equations and their errors.

Let us denote by $H_{m,n}$ the space of matrices of $m \times n$ dimension and define the scalar product in the space of matrices $H_{m,n}$: $\langle X_1, X_2 \rangle \triangleq SpX_1X_2^T$. Let A be a linear operator that acts from the space of matrices $H_{m,n}$ to the space of matrices $H_{r,s}$. Suppose that a given matrix $Y \in H_{p,q}$, which has the form

$$Y = CX + V, \tag{1}$$

where C is linear operator that acts from $H_{m,n}$ to $H_{p,q}$ space; X is unknown matrix from $H_{m,n}$ space, which is a solution of the operator equation

$$AX = F \tag{2}$$

for some unknown matrix $F \in H_{r,s}$; V is the unknown error matrix from the $H_{p,q}$ space.

We will find solutions to equation (2) that are optimal in a certain sense based on the known matrix Y and the known constraints on the V and F matrices. In general, equation (2) can have many solutions. It is known that solutions of equation (2) exist if the matrix F is orthogonal to the kernel of the A^* conjugate operator, i.e. $F \perp \ker A^*$, where $\ker A^* \triangleq \left\{ F^{(1)} : A^* F^{(1)} = 0 \right\}$. Under this condition, all solutions of equation (2) can be given in the form: $X = X^{(0)} + \Theta, \Theta \in \ker A$, where $X^{(0)}$ is the minimum by norm solution of equation (2).

In the future, we will assume that the matrix F has the form: $F = \rho_1(F) f + F_0$, where $\rho_1(F) f \triangleq \sum_{k=1}^{m_1} F_k f_k$, $F_k \perp \ker A^*$, $k \in \overline{1, m_1}$, $f = \left(f_1, f_2, ..., f_{m_1} \right)^T$ is unknown vector, F_0 is a known matrix from the $H_{r,s}$ space, such that $F_0 \perp \ker A^*$. With an unknown vector f and an

unknown matrix V, which belong to the given sets G_1 and G_2, respectively, we first find the set to which the solutions of the operator equation (2) belong and determine the optimal solution in a certain sense.

Let Φ_i, $i \in \overline{1, m_2}$ denote the orthonormal basis in the orthogonal complement to $\ker A$. Let's write the matrix Θ in the form: $\Theta = \sum_{i=1}^{m_2} \Phi_i g_i \triangleq \rho_2(\Phi) g$, where $g_i = \langle \Theta, \Phi_i \rangle$, $i \in \overline{1, m_2}$.

Note that since the matrix $X^{(0)}$ can be written in the form: $X^{(0)} = \sum_{i=1}^{m_1} X_i f_i + X_0$, where X_i, $i \in \overline{0, m_1}$ are the minimum by norm solutions of the equations $AX_i = F_i$, $i \in \overline{0, m_1}$, then the matrix Y has the form:

$$Y = C\rho_3(X) f + C\rho_2(\Phi) g + CX_0 + V, \tag{3}$$

where $\rho_3(X) f \triangleq \sum_{i=1}^{m_1} X_i f_i$. Denoting by β the vector $\beta = (f \ g)^T$, we rewrite expression (3) for the matrix Y as follows: $Y = C_1\beta + CX_0 + V$, where C_1 is a linear operator that acts from $R^{m_1} \times R^{m_2}$ space to the $H_{p,q}$ space of matrices, so that $C_1\beta = C\rho_3(X) f + C\rho_2(\Phi) g$.

Definition 1. We call the set $G_y(\beta)$:

$G_y(\beta) \triangleq \left\{\beta : \beta \in G_1 \times R^{m_2}, \tilde{Y} - C_1\beta \in G_2\right\}$ a posteriori set for the parameter β, where $\tilde{Y} = Y - CX^{(0)}$.

Definition 2. We define a posteriori set of solutions of the operator equation (2) as follows: $G_y(X) \triangleq \left\{X : \beta \in G_y(\beta)\right\}$.

Let's introduce sets:

$G_1^{(i)} \triangleq \left\{\beta : \left(Q_1^{(i)}\left(\beta - \beta_0^{(i)}\right), \beta - \beta_0^{(i)}\right) \le 1\right\}, G_2^{(i)} \triangleq \left\{V : \left(Q_2^{(i)} V, V\right) \le 1\right\}$, $i \in \overline{1,2}$,

where $Q_1^{(i)}$, $i \in \overline{1,2}$ are known nonnegative definite matrices; $Q_2^{(i)}$, $i \in \overline{1,2}$ are known nonnegative definite linear operators; $\beta_0^{(i)}$, $i \in \overline{1,2}$ are given vectors. Let us also assume that the inclusion of: $G_1^{(1)} \subseteq G_1 \times R^{m_2} \subseteq G_1^{(2)}$, $G_2^{(1)} \subseteq G_2 \subseteq G_2^{(2)}$. Then, for a posteriori set $G_y(\beta)$ the following inclusions $G_y^{(1)}(\beta) \subseteq G_y(\beta) \subseteq G_y^{(2)}(\beta)$ are performed, where

$$G_y^{(i)}(\beta) \triangleq \left\{\beta : \beta \in G_1^{(i)}, \left\langle Q_2^{(i)}\left(\tilde{Y} - C_1\beta\right), \tilde{Y} - C_1\beta\right\rangle \le 1\right\}, \; i \in \overline{1,2}.$$

Let's also introduce sets:

$$\bar{G}_y^{(1)}(\beta) = \left\{\beta : J_1(\beta) \le 1\right\}, \tag{4}$$

$$\bar{G}_y^{(2)}(\beta) = \left\{\beta : J_2(\beta) \le 2\right\}, \tag{5}$$

where

$$J_i(\beta) \triangleq \left(Q_1^{(i)}\left(\beta - \beta_0^{(i)}\right), \beta - \beta_0^{(i)}\right) + \left\langle Q_2^{(i)}\left(\tilde{Y} - C_1\beta\right), \tilde{Y} - C_1\beta\right\rangle, \; i \in \overline{1,2}.$$

Definition 3. The set $\bar{G}_y^{(1)}(\beta)$, defined by formula (4) will be called the lower approximation of a posteriori set $G_y(\beta)$, and the set $\bar{G}_y^{(2)}$, defined by formula (5) will be called the upper approximation of a posteriori set $G_y(\beta)$.

Let $B_i, \; i \in \overline{1,2}$ denote the set of minimum points of functions $J_i(\beta), \; i \in \overline{1,2}$.

Theorem 1. Let the vectors $\hat{\beta}_i \in B_i, \; i \in \overline{1,2}$. Then the equality $J_i(\beta) = J_i\left(\hat{\beta}_i\right) + \left(P_i\left(\beta - \hat{\beta}_i\right), \beta - \hat{\beta}_i\right), \; i \in \overline{1,2}$ holds, where $P_i = Q_1^{(i)} + C_1^* Q_2^{(i)} C_1, \; i \in \overline{1,2}$, and vectors $\hat{\beta}_i, \; i \in \overline{1,2}$ are found as solutions of the corresponding systems of algebraic equations:

$$P_i\hat{\beta}_i = C_1^* Q_2^{(i)}\tilde{Y} + Q_1^{(i)}\beta_0^{(i)}, \; i \in \overline{1,2}.$$

Let a posterior set of solutions of equation (2) be bounded and let $\tilde{X}$ – be some matrix that is a solution of equation (2).

Definition 4. The quantity $\sigma\left(\tilde{X}\right) = \sup\limits_{X \in G_y(X)} \left\|\tilde{X} - X\right\|$ is called the guaranteed a posteriori error of the estimate of the matrix (*GPEEM*) $\tilde{X}$.

Definition 5. The matrix $\tilde{\tilde{X}} \in Arg\min\limits_{\tilde{X}} \sigma\left(\tilde{X}\right)$ is called the guaranteed a posteriori estimate of the matrix (GPEM) $\tilde{X}$.

Theorem 2. Let the upper and lower approximations be taken as $\bar{G}_y^{(2)}(X)$ and $\bar{G}_y^{(1)}(X)$, respectively. Then the upper and lower GPEM X has the form:

$$\hat{X}^{(i)} = \rho_3(X)\hat{f}^{(i)} + \rho_2(\Phi)\hat{g}^{(i)} + X^{(0)}, \; i \in \overline{1,2},$$

where $\begin{pmatrix} \hat{f}^{(i)} \\ \hat{g}^{(i)} \end{pmatrix} = \hat{\beta}_i$, $i \in \overline{1,2}$ and at the same time, the upper and lower GPEEM are such that:

$$\sigma^{(i)} = \max_{X \in \bar{G}_y^{(i)}(X)} \left\| \hat{X}^{(i)} - X \right\| = \lambda_{\max}^{1/2} \left(\bar{P}_i \right) \left(i - J_2 \left(\hat{\beta}_i \right) \right)^{1/2}, \; i \in \overline{1,2},$$

where matrices $\bar{P}_i$, $i \in \overline{1,2}$ are calculated according to formulas:

$$\bar{P}_i = \begin{pmatrix} \rho_3(X) P_{11} \rho_3^*(X) & \rho_3(X) P_{12} \rho_2^*(\Phi) \\ \rho_2(\Phi) P_{21} \rho_3^*(X) & \rho_2(\Phi) P_{22} \rho_2^*(\Phi) \end{pmatrix}, \; P_i^{-1} = \begin{pmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{pmatrix},$$

$i \in \overline{1,2}$, $\|X\| = \langle X, X \rangle^{1/2}$.

References

1. Battey H., Fan J., Lu J., Zhu Z. Distributed testing and estimation under sparse high dimensional models // Annals of Statistics. – 2018. – Vol. 46 (3). – P. 1352 – 1382.
2. Ke T., Ma Y., Lin X. Estimation of the number of spiked eigenvalues in a covariance matrix by bulk eigenvalue matching analysis // arXiv preprint arXiv: 2006.00436, 2020.
3. Chatterjee S. Matrix Estimation by Universal Singular Value Thresholding // Annals of Statistics. – 2015. - Vol. 43(1). – P. 177-214.
4. Nakonechniy O.G., Kudin G.I., Zinko P.M., Zinko T.P. Perturbation method in problems of linear matrix regression // Journal of Automation and Information Sciences. – 2020. – Vol. 52(1). – P. 1–12.
5. Nakonechniy O.G., Kudin G.I., Zinko P.M., Zinko T.P. Approximate guaranteed estimates for matrices in linear regression problems with a small parameter // System Research & Information Technologies. - 2020. – № 4. – С. 88 – 102.
6. Nakonechniy O.G., Kudin G.I., Zinko P.M., Zinko T.P. Minimax root-mean-square estimates of matrix parameters in linear regression problems under uncertainty // Journal of Automation and Information Sciences. – 2021. – Vol.4. – P. 28 – 37.
7. Nakonechniy O.G., Kudin G.I., Zinko P.M., Zinko T.P., Shusharin Y.V. Guaranteed root mean square estimates of linear matrix equations solutions under conditions of uncertainty // Mathematical Modeling and Computing. – 2023. – Vol.10(2). – P. 474 – 486.
8. Nakonechniy O.G., Kudin G.I., Zinko P.M., Zinko T.P. Guaranteed root mean square estimates of the forecast of matrix observations under

conditions of statistical uncertainty // System Research and Information Technologies. – 2023. – Vol. 2. – P. 86 – 103.
9. Nakonechniy O.G., Zinko P.M. Estimates of matrix solutions of operator equations with random parameters under of uncertainties // Mathematychni Studii. – 2023. – Vol.60(2). – P. 208 – 222.

INTERCONNECTED SYSTEM OF RICCATI OPERATOR EQUATIONS

A. Oficerov
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine
andrej.ofitserov@gmail.com

We consider the following interconnected system of operator equations

$$A_{ii}X_i(\varepsilon) + X_i(\varepsilon)B_{ii} + \varepsilon\sum_{j=1,j\neq i}^{n} X_j(\varepsilon)C_{ij}X_j(\varepsilon) = D_{ii}, i = \overline{1,n},$$

where $A_{ii}, B_{ii}, C_{ij}, D_{ii} \in L(H)$ – are linear and bounded operators (matrices) which act in the Hilbert space *H*. We find a necessary and sufficient solvability conditions, iterative procedures for finding solutions $X(\varepsilon)$ which for $\varepsilon = 0$ turn in one of solutions $X^0 = X(0)$ of the linear generated problem. We will use methods which was obtained in the works [1-4].

References

1. Boichuk O.A., Pokutnyi O.O. Normally-resolvable boundary-value problems for the operator-differential equqtions. – Kyiv, Naukova dumka, 2022. – 222 p. (in Ukrainian). doi.org/10.37863/2843457491-61.
2. Boichuk O.A., Pokutnyi O.O. Perturbation theory of operator equations in the Frechet and Hilbert spaces // Ukrains'kyi Matematychnyi Zhurnal. – 2016. – No.9. – P.1327-1335. doi: 10.1007/s11253-016-1156-y.
3. Panasenko E.V., Pokutnyi O.O. Boundary-value problems for the Lyapunov equation in Banach spaces // Journal of mathematical sciences. – 2017. – Vol. 3. – P. 298-304. doi: 10.1007/s10958-017-3356-x.
4. Boichuk O.A., Panasenko E.V., Pokutnyi O.O. Boundary-value problems for the Lyapunov equation. II // Ukrains'kyi Matematychnyi Zhurnal. – 2024. – Vol. 5. – P. 680-694. doi: 10.3842/umzh.v76i4.7786.

METHOD OF MUTUAL AUTHENTICATION OF UAV SWARM ELEMENTS UNDER UNCERTAINTIES

M. Ogurtsov
V.M. Glushkov Institute of Cybernetics of the National Academy of Sciences of Ukraine, Ukraine
ogurtsov.maksym@incyb.kiev.ua

Today, the problem of individual UAVs authentication in a swarm is becoming more and more relevant. The goal of this work is to develop a method of mutual authentication of UAV swarm elements under uncertainties based on reinforcement learning for automatic detection and authentication of other UAVs in the swarm., using two parts of cryptographic keys – static and dynamic (which found out via learning process).

There are many approaches to authenticating swarm elements [1], [2], [3] but they rarely use reinforcement learning during the authentication.

A method and algorithm for mutual authentication of UAV swarm elements under uncertainties based on reinforcement learning was developed. The algorithm includes a set of static keys, pre-distributed among the UAV swarm elements, and dynamic keys, which are used together with static s to form a session key. Dynamic keys are never shared, instead other swarm elements learning to generate the dynamic keys of all other elements using reinforcement learning and the epsilon-greedy strategy. Practical experiments showed the applicability of the proposed method.

References

1. Bansal G., Biplab S. S-maps: Scalable mutual authentication protocol for dynamic uav swarms // IEEE Transactions on Vehicular Technology. – 2021. – 70.11. – P. 12088-12100.
2. Han P., Sui A., Wu J. Identity management and authentication of a UAV swarm based on a blockchain // Applied Sciences. – 2022. – 12.20. – P. 10524.
3. Hulianytskyi L., Ogurtsov M., Korolyov V. Development of the “friend-or-foe” identification system on the basis of programmable radiomodems // CEUR Workshop Proceedings. – 2023. – 3538. – P. 222–231.

SOLVING THE PROBLEM OF JOBS PRIORITIZATION UNDER LIMITED RESOURCES FOR THE CASE OF A SERVICE COMPANY

Y. Osmak
Taras Shevchenko National University of Kyiv, Ukraine
yevhen.osmak@knu.ua

This paper addresses the problem of decision-making regarding the prioritization and scheduling of maintenance and repair jobs on equipment under conditions of limited resources for the case of a service company. The author reviews modern approaches to predictive maintenance [1] and job shop scheduling problem (JSSP) [2], noting a gap in combining these two tasks for the service company's case. A mathematical model is proposed that formulates the problem as a mixed-integer linear programming problem (MILP) with the target of maximizing revenue and minimizing the total duration of the work execution under the limited resources of the service company. Directions for further research are outlined, such as application of fuzzy logic, machine learning for fuzzy number parameters identification, numerical experiments on real and synthetically generated data, and further multi-criteria optimization considering equipment downtime.

References

1. Arena F., Collotta M., Luca L., Ruggieri M., Termine F.G. Predictive Maintenance in the Automotive Sector: A Literature Review, 27, 2 ed. – Basel, Switzerland: Math. Comput. Appl, 2022.
2. Demir Yu., İşleyen S.K. Evaluation of mathematical models for flexible job-shop scheduling problems. // Applied Mathematical Modelling. – 2013. – Vol. 37(3). – P. 977-988.

DECISION-MAKING UNDER UNCERTAINTY: EXPLORING CONSUMER BEHAVIOR AND ITS IMPLICATIONS IN ECONOMICS AND BUSINESS

Marine Papunidze
Batumi Shota Rustaveli State University, Batumi, Georgia

This study investigates the intricate dynamics of consumer decision-making processes amid economic uncertainty, aiming to provide a comprehensive understanding and actionable insights for businesses in navigating complex economic landscapes. The research employs a

multidisciplinary approach, integrating perspectives from behavioral economics, psychology, and market analysis.

Consumer behavior in uncertain economic environments is shaped by a multitude of factors, including psychological biases, risk perception, and social influences. Understanding these dynamics is crucial for businesses seeking to adapt their strategies effectively. The theoretical framework of this study draws from prospect theory, decision heuristics, and behavioral economics to explore how consumers assess and respond to varying levels of uncertainty.

The empirical phase of this research involves extensive quantitative analysis, which uses large-scale consumer behavior datasets across diverse sectors, employing advanced statistical methods and econometric models to uncover patterns and trends. Through regression analysis and econometric modeling, the study identifies key drivers of consumer behavior under varying economic conditions, highlighting the significance of price sensitivity, brand loyalty, and product differentiation strategies.

In conclusion, this research contributes to advancing the theoretical understanding of decision-making under uncertainty in consumer behavior. By integrating insights from behavioral economics, psychology, and empirical analysis, this study provides a holistic framework for understanding and predicting consumer behavior in uncertain economic environments. The practical implications derived from this research will empower businesses to adapt their strategies proactively and capitalize on emerging opportunities in dynamic market landscapes.

AI APPROACH FOR WEB REAL-TIME COMMUNICATION CONGESTION CONTROL

A. Pashko[1], O. Bedzir[2]
[1]Taras Shevchenko National University of Kyiv, Ukraine
[2]Newxel, Ukraine
aapashko@gmail.com, Eshil.sn@gmail.com

WebRTC protocol is standard for the real-time communication in the web. Existing [1] peer to peer bandwidth adaptation algorithms uses percentage of lost package or estimation of delay trend for controlling bandwidth. The most critical problem on routers between two peers is congestion. Let S_i – ith packet send time and R_i – ith packet receive time.

The size of congestion on router is time (d_i) that packet spend in router sending queue.

In case of congestion on one router we can use $(R_i - R_{i-1}) - (S_i - S_{i-1}) \approx RTT + (d_i - d_{i-1})$ [2]. Unfortunately, it can't be used for difficult system with multiple routers. Proposed algorithm uses self-learning algorithm for estimation and prediction of congestion. It allows better estimate for available bandwidth and personalization for each unique situation.

References

1. Carlucci G., De Cicco L., Holmer S., Mascolo S. Analysis and Design of the Google Congestion Control for Web Real-time Communication (WebRTC) Proc. ACM Mmsys 2016, Klagenfurt, Austria, May 2016

2. Holmer S., Lundin H., Carlucci G., De Cicco L., Mascolo S. A Google Congestion Control Algorithm for Real-Time Communication IETF draft RMCAT wg, draft-ietf-rmcat-gcc-01, Oct 2015.

WIRELESS SENSOR NETWORKS FOR SYSTEMS. OVERVIEW OF EMBEDDED SYSTEMS

O. Peregontsev

Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine

peregoncev1952@ukr.net

An embedded system is a specialized computing system that performs dedicated functions within a larger mechanical or electrical system. Unlike general-purpose computers, embedded systems are designed to handle specific tasks, often with real-time constraints.

Embedded systems are designed to perform a specific function or a set of functions, often with a high degree of specialization.

Many embedded systems operate in real-time, meaning they must process and respond to inputs within a defined time frame to ensure correct operation.

Embedded systems must operate reliably and stably over long periods, often in challenging environments.

The architecture of an embedded system can vary widely depending on its application and requirements including:

Microcontroller or Microprocessor: The core processing unit of an embedded system, responsible for executing instructions and controlling other components. Microcontrollers integrate processing, memory, and I/O interfaces on a single chip, while microprocessors typically require

external components.

Memory: Embedded systems use different types of memory for program storage and data processing.

Input/Output Interfaces: These interfaces enable the embedded system to interact with external devices and systems.

Sensors and Actuators: Sensors collect data from the environment, while actuators perform actions based on the processed data.

Power Supply: Embedded systems require a stable power supply, which can be provided by batteries, power adapters, or energy-harvesting methods.

Software and Firmware: The software and firmware of an embedded system define its functionality and behavior. This includes the operating system, device drivers, application code, and real-time operating systems (RTOS) for real-time applications.

Embedded systems are ubiquitous and find applications in various domains.

AUTOMATED DECISION MAKING TRAJECTORY BUILDING SYSTEM

Volodymyr Petrivskyi, Oleksii Bychkov
Taras Shevchenko National University of Kyiv, Ukraine
volodymyr.petrivskyi@knu.ua, oleksiibychkov@knu.ua

Sensors are widely used in the modern world. A very large number of problems are solved using sensors [1]. In addition to sensors that do not change their position in space, there are sensors that move. The main problem when using such sensors is the construction of the optimal trajectory of movement. The authors proposed an algorithm for constructing the optimal trajectory of the overflight of the territory using the principle of dynamic programming [2, 3]. The main idea of the developed algorithm is to discretize the movement process and choose the direction of movement of the sensor at each step. The criterion of optimality is the coverage of the maximum area of the territory at each step. The developed algorithm allows you to automatically choose the direction of movement of the sensor at each step, which results in choosing the optimal direction of movement and covering most of the area under consideration. The algorithm consists of the following stages: selection of the starting point of movement, selection of the size of the step, selection of movement directions, calculation of the area of the

covered territory at each step, movement in the direction with the largest area of coverage of the territory.

References

1. Surenther I., Sridhar K. P., Roberts M. K. Maximizing energy efficiency in wireless sensor networks for data transmission: A Deep Learning-Based Grouping Model approach. // Alexandria Engineering Journal. – 2023. – Vol.83. – P. 53–65. URL: https://doi.org/10.1016/j.aej.2023.10.016.

2. Petrivskyi V., Bychkov O., Martsenyuk V. Proving the Existence of Solutions to the Problems of Minimizing the Energy Consumption of Sensor Networks. // Applied Sciences. – 2022. – Vol. 12(15). – 7687. URL: https://doi.org/10.3390/app12157687.

3. Petrivskyi V. et al. A Method for Maximum Coverage of the Territory by Sensors with Minimization of Cost and Assessment of Survivability. // Applied Sciences. – 2022. – Vol. 12(6). – 3059. URL: https://doi.org/10.3390/app12063059.

ESTIMATION OF PARAMETERS IN ECONOMIC MODELS WITH GENERALIZATIONS

D. Pogorielov

Kyiv University of Management and Entrepreneurship, Ukraine

dmitrii.pogorielov@gmail.com

We consider estimation of parameters in such like a Cobb-Douglas with linear perturbations in the right-hand sides

$$f(K,L) = AK^{\alpha}L^{\beta}, f(x_1, x_2, \dots, x_n) = Ax_1^{\alpha_1}x_2^{\alpha_2} \dots x_n^{\alpha_n}$$

or $f(x_1, x_2, \dots, x_n, \dots) = A\prod_{k=1}^{\infty} x_k^{\alpha_k}$. We consider such perturbations for the linear regression for the logarithm of the considered model

$$y_{\varepsilon} = y + \varepsilon y_1 = lnf_{\varepsilon}(K,L) = lnA + \alpha\, lnK + \beta lnL ,$$

$lnf_{\varepsilon}(x_1, x_2, \dots, x_n) = lnA + \sum_{k=1}^{n} \alpha_k ln\, x_{k,}$ where n can be infinite. In such case we consider corresponding problem in the Hilbert space l_2. We will use results obtained in [1-4].

References

1. Boichuk O.A., Pokutnyi O.O. Normally-resolvable boundary-value problems for the operator-differential equqtions. – Kyiv, Naukova dumka, 2022. – 222 p. (in Ukrainian). doi.org/10.37863/2843457491-61.

2. Boichuk O.A., Pokutnyi O.O. Perturbation theory of operator equations in the Frechet and Hilbert spaces // Ukrains'kyi Matematychnyi Zhurnal.

– 2016. – No.9. – P.1327-1335. doi: 10.1007/s11253-016-1156-y.
3. Panasenko E.V., Pokutnyi O.O. Boundary-value problems for the Lyapunov equation in Banach spaces // Journal of mathematical sciences. – 2017. – Vol. 3. – P. 298-304. doi: 10.1007/s10958-017-3356-x.
4. Boichuk O.A., Panasenko E.V., Pokutnyi O.O. Boundary-value problems for the Lyapunov equation. II // Ukrains'kyi Matematychnyi Zhurnal. – 2024. – Vol. 5. – P. 680-694. doi: 10.3842/umzh.v76i4.7786.

BRANCHING SOLUTIONS FOR THE INTERCONNECTED SYSTEM OF LYAPUNOV EQUATIONS WITH CONTROL

O. Pokutnyi, O. Iskra
Taras Shevchenko National University of Kyiv, Ukraine,
Institute of mathematics of NAS of Ukraine
alex_poker@imath.kiev.ua, oleg.iskra@imath.kiev.ua

We consider the following system of operator equations:

$$\begin{cases} A_{22}X_2(\varepsilon) + X_2(\varepsilon)B_{22} + \\ + \varepsilon R_1\big(X_2(\varepsilon), X_3(\varepsilon), \dots, X_n(\varepsilon)\big) + C_1U_1 = H_1, \\ A_{22}X_2(\varepsilon) + X_2(\varepsilon)B_{22} + \\ + \varepsilon R_2\big(X_1(\varepsilon), X_3(\varepsilon), \dots, X_n(\varepsilon)\big) + C_2U_2 = H_2, \\ \dots \\ A_{nn}X_n(\varepsilon) + X_n(\varepsilon)B_{nn} + \\ + \varepsilon R_n\big(X_1(\varepsilon), X_2(\varepsilon), \dots, X_{n-1}(\varepsilon)\big) + C_nU_n = H_n. \end{cases} \quad (1)$$

with additional conditions $l_iX_i(\varepsilon) = \alpha_i$. Here A_{ii}, B_{ii}, C_i, H_i – are linear and bounded operators in the Hilbert space $\mathcal{H}$, $U_i \in L(\mathcal{H})$ – are control operators, l_i are linear and bounded ope-rators which translates solutions of the nonlinear system (1) into another Hilbert space $\mathcal{H}_1$, R_i – are nonlinearities with additional conditions. We find solutions $X_i(\varepsilon)$ of (1) which for $\varepsilon = 0$ turn in one of solution $X_i^0 = X_i(0)$ of the corresponding unperturbed linear problem. We will use results which was obtained in the works [1-2].

References

1. Boichuk O.A., Pokutnyi O.O. Normally-resolvable boundary-value problems for the operator-differential equqtions. – Kyiv, Naukova dumka, 2022. – 222 p. (in Ukrainian). doi.org/10.37863/2843457491-61.
2. Boichuk O.A., Pokutnyi O.O. Perturbation theory of operator equations in the Frechet and Hilbert spaces // Ukrains'kyi Matematychnyi Zhurnal. – 2016. – No.9. – P.1327-1335. doi: 10.1007/s11253-016-1156-y.

INTELLIGENT DATA ANALYSIS IN THE 'KNOWLEDGE ECONOMY'

Maxim Polyakov, Igor Khanin, Gennadij Shevchenko, Vladimir Bilozubenko
Noosphere Ventures Corporation, Ukraine
info@noosphereventures.com, i.h.khanin@nuwm.edu.ua, nikk.gena@gmail.com bvs910@gmail.com.

Nowadays, the economy generates and processes a huge amount of data; the main purpose of obtaining this data is to prepare the right decision making. However, it is not the data itself that is needed, but the information based on it that can be used to make a justified decision. For economics, it is possible to distinguish three types of information influencing decision making and related to the capability to measure it: assumption, opinion, knowledge. The boundaries between them are very blurred, but this approach enables assessments of the reliability of the available information to be made. In these contexts, the so-called intelligent data analysis (IDA) has become widely used.

At the same time, the understanding of its role in the economy is quite fragmentary. A systematic way of considering the methods, purpose, varieties, directions of application of IDA is needed. The issues related to understanding the limits of IDA in terms of cognitive theory are relevant, which can help businesses to correctly assess their prospects.

The practice of analytical work shows that IDA really promotes the solution of a significant number of applied problems in economics. De facto, it has become a part of analytical research in economics and business, necessary to support managerial decision-making, intellectualisation of selection operations, automation of a number of processes in marketing, logistics, finance, security and so on. It is important to note that the knowledge obtained from the data through the use of IDA methods is empirical in nature. Nevertheless, they act as a source of new value creation in the economy and competitive advantage, with all its consequences. IDA provides an initial stage, highlighting empirical regularities as a basis for further in-depth analyses, for the transition from the empirical level of cognition to understanding and to the theoretical level. This enhances forecasting capabilities and enables larger and longer-term decision making (Data-to-Insight-to-Decision). This is exactly the kind of knowledge you need to make strategic decisions in business.

INFLUENCE OF EXPLAINABLE AI ON THE ARCHITECTURE OF TEXT CLASSIFICATION MODELS

A. Pylypenko
Taras Shevchenko National University of Kyiv, Ukraine,
anna.pylypenko@knu.ua

Recent advancements in AI have significantly improved text classification models' accuracy and complexity. However, their "black box" nature, which lacks transparent explanations for decisions, hinders widespread adoption. Explainable AI (XAI) addresses this by transforming these models into interpretable ones. The seminal work [1] introduced Local Interpretable Model-agnostic Explanations (LIME), which explains any classifier's predictions, enhancing trust and understanding.

Different neural network architectures impact the interpretability and accuracy of text classification models in various ways. CNNs capture local dependencies and identify important features, providing interpretable explanations through visualization techniques. RNNs, especially LSTM and GRU, handle long-range dependencies and enhance interpretability by tracing information flow and using attention mechanisms. Transformer models like BERT utilize self-attention to efficiently capture global dependencies. Although transformers typically achieve higher accuracy, they require advanced techniques for interpretability. Balancing transparency and predictive power in these architectures remains a key research focus.

The ethical implementation of XAI in text classification is crucial, emphasizing transparency, fairness, accountability, and privacy. Transparency involves making AI models understandable, fostering user trust. Fairness requires identifying and mitigating biases to promote equality. Accountability ensures that transparent models hold developers responsible for outcomes, which is vital in sensitive applications like legal or medical text analysis. Balancing transparency with privacy protection safeguards individual data. Addressing these ethical aspects enhances AI systems' trustworthiness and alignment with societal values.

References

1. Ribeiro M., Singh S., Guestrin C. ‘Why Should I Trust You?’: Explaining the Predictions of Any Classifier// Proceedings of the 2016 Conference of the North American Chapter of the Association for Computational Linguistics: Demonstrations, 2016, doi: https://doi.org/10.18653/v1/n16-3020.

CONSTRAINED DISTURBANCES SUPPRESSION FOR MULTIRATE IMPULSE PROCESSES IN COGNITIVE MAPS OF CRYPTOCURRENCY APPLICATIONS

Viktor Romanenko, Yurii Miliavskyi, Heorhii Kantsedal
Igor Sikorsky Kyiv Polytechnic Institute, Ukraine
romanenko.viktorroman@gmail.com, yuriy.milyavsky@gmail.com, g.kantsedal@protonmail.com

In this report a cognitive map (CM) of cryptocurrency application in the financial market is developed, based on which the dynamic model of impulse processes of CM in the form of a system of difference equations (Roberts equations) with multirate sampling is described. The original CM model is decomposed into subsystems with fast- and slow-measured node coordinates. The realization of external control vectors for the subsystem with fast-measured and slow-measured node coordinates by varying some coordinates that can be measured by a decision maker is performed. Closed-loop subsystems of CM impulse process control are implemented, which include multidimensional discrete controllers designed based on the method of invariant ellipsoids. The problem of designing the discrete-time controllers for suppression of constrained internal and external disturbances is solved. External disturbances include a variety of information disturbances acting on the system. Internal disturbances include changes in the influence of CM nodes on each other, for instance, fluctuations of weight coefficients of CM with respect to their basic values. The mutual influence of interconnected CM subsystems on each other is also taken into account as disturbances. The designed control is implemented by a decision maker. By numerical simulation, the efficiency of the designed discrete controllers was investigated and the system performance was compared in the presence and absence of controls [1].

References

1. V. Romanenko, Y. Miliavskyi, H. Kantsedal. Application of Impulse Process Models with Multirate Sampling in Cognitive Maps of Cryptocurrency for Dynamic Decision Making // In: System Analysis & Intelligent Computing. Theory and Applications. Eds: M. Zgurovsky, N. Pankratova. – Springer, 2022. – P. 115-137.

STATISTICAL METHODS FOR IMPULSE RESPONSE FUNCTION ESTIMATION IN LINEAR SYSTEMS

I. Rozora, A. Melnyk
Taras Shevchenko National University of Kyiv, Ukraine
irozora@knu.ua, melinik2011@gmail.com

The study focuses on estimating the impulse response functions of continuous linear systems. These systems are characterized by real-valued impulse response functions defined on a bounded domain. The estimation method involves using an input-output cross-correlogram, based on zero-mean stationary Gaussian processes represented through Fourier expansions.

The research introduces goodness-of-fit testing of the impulse response function, utilizing the theory of square-Gaussian stochastic processes. It calculates the probability of large deviations for estimation errors in the space of square-integrable functions, enhancing the estimator's accuracy and reliability.

Key results include the estimation of mathematical expectation, variance, unbiasedness and consistency of the estimator when the input process is represented using a trigonometric basis. Additionally, the study features software simulations to determine critical values for the averaging interval, demonstrating the estimator's performance with sample paths for input and output processes.

References

1. Kozachenko, Y., & Rozora, I. (2016). Cross-correlogram estimators of impulse response functions. Theory of Probability and Mathematical Statistics, 93, 79-91.
2. Kozachenko, Y., & Rozora, I. (2023). On statistical properties of the estimator of impulse response function. Stochastic Processes, Statistical Methods, and Engineering Mathematics, 408, 563-586.

ENHANCING SPEAKING SKILLS: EVALUATING THE IMPACT OF THE DIAMOND METHOD IN EFL EDUCATION

Nino Samnidze, Medea Diasamidze
Batumi Shota Rustaveli State University, Georgia

This research paper aims to investigate the effectiveness of the Diamond Method in enhancing speaking skills among English as a Foreign Language (EFL) students. The Diamond Method is a teaching approach that focuses on four essential components of speaking: fluency, accuracy, complexity, and appropriacy. This paper employs a mixed-method research design, combining quantitative and qualitative data collection and analysis techniques. The participants in this study are EFL students enrolled in an intermediate-level English course at a university in Georgia.

The qualitative data were collected through observations, interviews, and self-reflection reports to gain a deeper understanding of the students' experiences with the Diamond Method. The results of the study indicated that the implementation of the Diamond Method had a positive impact on the speaking skills of EFL students. The participants demonstrated improvements in fluency, accuracy, complexity, and appropriacy in their spoken English. Furthermore, the qualitative findings revealed that the Diamond Method facilitated a more engaging and interactive learning environment, encouraging students to take risks, collaborate, and communicate effectively.

This research contributes to the existing body of knowledge on effective teaching methods for developing speaking skills in EFL contexts in Georgia. The findings highlight the importance of integrating a holistic approach that considers various dimensions of speaking proficiency. The Diamond Method provides a structured framework that helps teachers create dynamic speaking activities, fostering an immersive and communicative language learning experience. However, it is important to note that the study was conducted with a specific group of EFL students in a particular educational setting. Further research is recommended to explore the applicability and effectiveness of the Diamond Method across different EFL contexts and student populations.

METHODS AND ALGORITHMS OF ARTIFICIAL INTELLIGENCE IN MOBILE MEDICAL COMPLEXES

S. Samoilov
Ukrainian State University of Science and Technology, Ukraine
ssp67kn@gmail.com

Artificial intelligence (AI) plays an important role in the diagnosis and treatment of diseases. Some AI methods and algorithms that are used to create diagnostic and treatment systems:

Machine Learning and Diagnostics: Machine learning has enormous potential in the field of medical diagnostics. It can analyze millions of patient records, identify hidden correlations, and predict the likelihood of certain diseases in a given patient. This helps doctors develop an individualized approach to diagnosing and treating patients.

Treatment applications: AI can analyze patient medical data and identify patterns that may not be obvious to humans. This helps healthcare professionals determine optimal treatment regimens and predict the effectiveness of certain medications.

Genetic data analysis: AI is applied in genetic data analysis, where machine learning algorithms can identify genetic mutations associated with inherited diseases and provide recommendations for personalized treatment and prevention.

Some examples of the use of artificial intelligence (AI) in medical diagnostics. **Cancer diagnosis**: AI can be used to analyze medical images, such as mammograms and MRI scans, to detect signs of cancer in the early stages. **Cardiovascular disease**: AI can analyze ECG data and other medical data to predict the risk of cardiovascular disease. **Diabetes**: AI can be used to analyze patient data and predict diabetes risk. **Robotic surgery**: AI is used in robotic surgical systems to assist in complex surgeries. Research has shown that the use of AI can reduce complications. **Skin cancer detection from photos:** AI can analyze skin photos to detect signs of skin cancer. **Blood pressure drop monitoring**: AI can be used to monitor patients and alert doctors to possible drops in blood pressure.

These examples highlight the potential of AI to improve diagnostic accuracy and predict treatment outcomes.

TWO-SIDED METHODS FOR SOLVING INTEGRAL EQUATIONS

P.S. Senio
Ivan Franko National University of Lviv, Ukraine
petrosny@ukr.net

Two-sided approximations of the integral equation solution

$$y(x) = f(x) + \int_a^x k(x, s, y(s))\, ds\,, \qquad (1)$$

where the function $f(x)$ is known, $y(x)$ is the desired function, $x \in [a, b]$, obtained by applying the mathematics of functional intervals. Thus, we obtain the solution of equation (1) in the form of a functional interval [1], which is guaranteed to contain this solution, and the width of this functional interval is not greater than however small value set by us.

Let $y(x)$ once be continuously differentiable in the interval $[a, b]$. Then we construct the initial two-sided approximation of the solution of equation (1) in the form of a functional interval according to the basic principle of the development of functional dependence [1, 2] and the fact that $y(a) = f(a)$. Substituting this functional interval into the integral of equation (1), we obtain the integral $\int_a^x K(s)\, ds$ of the linear functional interval $K(s) = \{[a, x],\ f^{(1)}(s),\ f^{(2)}(s)\}$ of its kernel $k\big(x, s, y(s)\big)$. This makes it possible to build methods for solving the integral equation (1) using the principle of consistency of localization of uncertainties based on the consistency of two-sided approximations of the function and its derivative [2].

References

1. Senio P.S. Some applications on the mathematics of functional intervals // Mathematical and Computer Modeling. Series: Physical and Mathematical Sciences. – 2016. – Vol. 13. – P. 182-193.
2. Senio P.S. Two-sided methods of solving the Cauchy problem based on the mathematics of functional intervals // Lviv University Bulletin. Ser. app. math and info. – 2017. – Vol. 24. – P. 18 -37.

DECOMPOSITION METHOD FOR SOLVING PARTIALLY DISCRETE BILINEAR OPTIMIZATION PROBLEMS

V.V. Semenov, D.S. Kolesnikov, I.M. Fateeva
Glushkov Institute of Cybernetics of NAS of Ukraine
semenov.jr@gmail.com, danylokolesnikov@gmail.com, mbird@i.ua

Many applications of bilinear programming have been reported in the literature and several techniques have been developed for solving continuous and partially integer problems [1,2]. Mixed discrete bilinear optimization problems considering the combinatorial configurations of the permutations with related variables is investigated: $\min \ \langle c,x\rangle+\langle x,Qy\rangle+\langle d,y\rangle \mid Ax+G(y)\geq b, y\in S\subset R^q$, where $c,x\in R^n$, $d,y\in R^q$, $b\in R^m$, $Q\in R^{n\times q}$, $A\in R^{m\times n}$, $G(y)=(g_1(y),...,g_m(y))$, $S-$ combinatorial space. These problems have two sources of noconvexity: combinatorial variables and bilinear functions. As is generally known, nonconvex problems have plenty of local solutions, distant at a global optimum, and classic methods of convex optimization in similar problems directly inapplicable or ineffective. These problems are NP-hard. Also investigated polyhedral properties of feasible region these problems. New exact and approximate decomposition algorithms for solving mentioned problems were constructed and justified. Specified algorithms are based on a combination of ideas Benders' method [3], relaxation [3, 4] and polyhedral approach [5] for partially combinatorial problems. It allows replacing the solving original problem to the solving sequence of simpler associate subproblems. Promising direction develops on the basis of the offered method of decomposition. These are new original algorithms for the solving of bilinear problems, using parallel computing.

References

1. Semenova N.V., Oliinyk S.V. Solving mixed integer bilinear optimization problems using decomposition method. // Journal of Computational & Applied Mathematics. – 2015. – Vol.3 (120). – P. 69–76.
2. Adams W.P., Sherali H.D. Mixed integer bilinear programming problems. // Mathematical Programming. – 1993. – Vol.59. – P. 279-305.
3. Benders J.F. Partitioning procedures for solving mixed-variables programming problems //Numerische Mathematik. – 1962. – 4,3. – P.238-252.
4. Lasdon L. Optimization theory for large systems. – New York: MacMillan, 1975.
5. Semenova N.V., Kolechkina L.M. Vector problems of discrete optimization

on combinatorial sets: methods of research and decision. – Kyiv: Sciences idea, 2009. – 266 p. (in Ukrainian).

ANALYSIS OF AVAILABLE ARTIFICIAL NEURAL NETWORKS AS AN ASSISTANT FOR CREATING COMPUTER PROGRAMS

D. Shabanov
Taras Shevchenko National University of Kyiv, Ukraine
dmytroshabanov@knu.ua

In recent years, many products utilizing artificial neural networks to assist programmers in coding within their chosen programming language have emerged.

This study was conducted to evaluate the quality of the code generated by artificial neural networks by such metrics as code validity, code correctness, code reliability, code maintainability, and generation speed. The weaknesses and strengths of the selected neural networks were identified based on the results obtained.

In this regard, a study was conducted of various such products that are currently in the public domain. Several neural networks were selected for comparison, including ChatGpt, Github Copilot, Gemini, and Claude. The code for evaluation was generated using the HumanEval-XL dataset. The resulting code was evaluated for correctness and reliability. To evaluate the maintainability of the code, the code was also checked for code smells and how much effort it takes to clean them up.

Based on the analysis, ChatGpt had the best code quality. The code generated with it was more often correct and required less effort to remove code smells. However, the generation speed was not its strong point. At the same time, Claude had a fairly good code quality and generates faster than GhatGpt. Github Copilot is a bit inferior to the previously mentioned models in quality, but its big advantage was that it is integrated into the IDE, which made it faster and more convenient to use. Gemini didn't have the best code quality, but it had quite a large available context. This can be useful if you need to reference a very large amount of existing code to solve a problem. While all of the above models had closed-source code, CodeLlama is an open-source model. The analysis showed that he had quite good code quality. Therefore, we can choose this option if we need to have an independent model and we have

guarantees that no third party has access to the data that the model uses and generates.

ON THE NEWTON-BROYDEN METHOD FOR SOLVING SYSTEMS OF THE NONLINEAR EQUATIONS

S.M. Shakhno, H.P. Yarmola
Ivan Franko National University of Lviv, Ukraine
stepan.shakhno@lnu.edu.ua, halyna.yarmola@lnu.edu.ua

Let us consider a system of the nonlinear equations [1]

$$H(x) = F(x) + G(x) = 0 \qquad (1)$$

with operator decomposition. Here F and $G : D \subset R^n \to R^n$ are nonlinear vector-valued functions, F is a differentiable function, G is a continuous function. For numerical solving of the equation (1) the methods with divided differences and methods with the operator decomposition are applied. In papers [1, 2], there was proposed and studied the Broyden-like method.

To find the approximate solution x^* of the system (1) we use the Newton-Broyden method

$$x^{(k+1)} = x^{(k)} - [F'(x^{(k)}) + B_k]^{-1} H(x^{(k)}),\ k = 0,1,.... \qquad (2)$$

Here the matrix B_{k+1} is defined by the following formula

$$B_{k+1} = B_k + \frac{(y_k - B_k s_k) s_k^T}{s_k^T s_k},$$

where $s_k = x^{(k+1)} - x^{(k)}$, $y_k = G(x^{(k+1)}) - G(x^{(k)})$ and the starting matrix $B_0 = G(x^{(-1)}, x^{(0)})$ is computed as the matrix of the first order divided difference for the vector-valued function G.

We provide a local convergence analysis of the method (2) under classical Lipschitz conditions for the derivatives and divided differences of the first order. The radius of convergence ball and error estimates are determined. The results of numerical experiments confirm the effectiveness of the method (2).

References

1. Chen X. On the convergence of Broyden-like methods for nonlinear equations with nondifferentiable terms // Annals of the Institute of Statistical Mathematics. – 1990. – Vol. 42. – P. 387-401.

2. Argyros I.K. On the convergence of Broyden-Like methods // Acta Mathematica Sinica, English Series. – 2007. – Vol. 23(11). – P. 2087-2096.

CONVERGENCE OF LEARNING PROCESSES IN DISCRETE EQUATIONS OF NEURAL NETWORKS DYNAMICS

T.I. Shakotko
Taras Shevchenko National University of Kyiv, Ukraine
tetiana.shakotko@knu.ua

This report represents the results of a study of stability of discrete dynamical processes in Hopfield neural networks and obtaining estimates of the convergence of neural networks learning processes. The dynamics of the processes are described by means of discrete equations. The research implements Liapunov's second method. The formation of constructive convergence estimates in dynamic Hopfield models describing the dynamics of discrete systems is conducted.

Mathematical models of the neural networks dynamics, described by nonlinear differential equations with a distinguished asymptotic stability of the diagonal part are considered in a number of researches, e.g. [1]. It should be noted that in general it is appropriate to use a discrete dynamic systems method rather than method of differential equations. The discrete models are even more appropriate models in view of an aftereffect. The discrete analogue of Lyapunov's second method can be used as the method of research of such systems. [2].

This report discusses discrete Hopfield neural networks, presented in a standard form

$$\Delta y_i(k) = -a_i y_i(k) + \sum_{j=1}^{n} \omega_{ij} \phi_j\left(y_j(k)\right) + I_i^0 \ , \ t \geq 0 \ , \ i = \overline{1,n} \ . \qquad (1)$$

It is assumed that the coefficients of the linear terms are sufficiently small and the nonlinear functions are limited. The report represents the conditions for the asymptotic stability of the learning processes described by the system (1) and the convergence coefficients of the process.

References

1. Hale Jack K., Verduyn Lunel Sjoerd M. Introduction to Functional Differential Equations. – Springer-Verlag, New-York-Berlin-Ytidelberg-London-Paris, 1991.

ENHANCING WARFARE STRATEGIES THROUGH LANCHESTER-TYPE MODELING AND OPTIMIZATION

M. Shcherbatyy
Ivan Franko National University of Lviv, Ukraine
mykhaylo.shcherbatyy@lnu.edu.ua

This research explores the extension of the classical Lanchester model to incorporate units within military forces, enhancing the model's fidelity in simulating complex combat scenarios [1].

Consider a military conflict between two opposing forces R and B, each of which is divided into n_R and n_B units R_i, $i=\overline{1,n_R}$, B_j, $j=\overline{1,n_B}$. The dynamics of the battle during the time $(t_0,t_e]$ are described by initial value problem for ODEs:

$$\begin{cases} R_i'(t) = -\alpha_{Ri}R_i(t) - \sum\limits_{j=1}^{n_B}\beta_{Rj}B_j(t) - \sum\limits_{j=1}^{n_B}\gamma_{Rij}R_i(t)B_j(t) + u_{Ri}(t), \\ B_j'(t) = -\alpha_{Bj}B_j(t) - \sum\limits_{i=1}^{n_R}\beta_{Bi}R_i(t) - \sum\limits_{i=1}^{n_B}\gamma_{Bji}B_j(t)R_i(t) + u_{Bj}(t), \end{cases} \quad (1)$$

$$R_i(t_0) = R_{i0}, \quad B_j(t_0) = B_{j0}, \quad i=\overline{1,n_R}, \quad j=\overline{1,n_B}, \quad (2)$$

where α_{Ri}, α_{Bj} - non-combat attrition rate for units R_i and B_j; β_{Rj}, β_{Bi}, γ_{Rij}, γ_{Bji} - rates of attrition during aimed and un-aimed fire properly; u_{Ri}, u_{Bj} - the rate of reinforcements. Combat and non-combat attrition rates are non-negative. The reinforcement coefficient can be positive, zero, or negative (reinforcements are supplied or some combat units are withdrawn). Certain model parameters are considered as functions of time.

On the basis of models (1)-(2), optimization problems are formulated, which consist in the optimal choice of model parameters to achieve the required combat results. Numerical simulations and optimization analysis demonstrate the model's capabilities in capturing various combat scenarios.

References

1. Kress M. Lanchester Models for Irregular Warfare // Mathematics. – 2020. – Vol. 8(5). – 737. https://doi.org/10.3390/math8050737.

VALUE-AT-RISK MEASURING FOR SUBDIFFUSION OPTION PRICING MODELS

N. Shchestyuk, S. Tyshchenko
National University "Kyiv-Mohyla Academy", Ukraine
Nataliya.shchestiuk@ukma.edu, Natalyshch@gmail.com

The value-at-risk is a useful tool for investors and can be used for understanding the past and making medium-term and strategic decisions for the future. The paper focuses on the risk measuring in the option price subdiffusive model under the unusual behavior of the market, when the price may not be changed for some time, which is quite a common situation in modern illiquid financial markets or during global crises.

The risk-free bond and classical geometrical Brownian motion (GBM) are time-changed by an inverted inverse Gaussian (IG) subordinator in the model. For option pricing, the two techniques were considered. The first very common approach for the time-changed model is to find option prices as the discounted expected payoff under the risk-neutral measure. The second technique for option pricing is based on a fractional version of what is called Dupire's equation.

The Value-at-Risk evaluating procedure for the proposed model was discussed and we show that this procedure is based on the Fractional Fokker-Planck equation (FFPE).

References

1. Shchestyuk N., Tyshchenko S., Drin S. Risk evaluating for subdiffusive option price model with Gamma subordinator. // Mathematical and Statistical Methods for Actuarial Sciences and Finance. (MAF 2024). – Springer, 2024.
2. Shchestyuk N., Tyshchenko S. Monte-Carlo method for option pricing in sub-diffusive arithmetic models. // Bulletin of T. Shevchenko National University of Kyiv. Series: Physics and Mathematics. – 2021. – Vol.2. – P. 85-95.

SHORT-TERM FORECASTING OF GAS AIR USING METHODS OF SYSTEM ANALYSIS

I. Shevchuk, A. Subotina
Taras Shevchenko National University of Kyiv, Ukraine
shevchuk.iuliia@knu.ua

Today, in almost all spheres of our life, there is a need for forecasting, such as predicting tomorrow's currency exchange rate, weather forecast, earthquake prediction. Building mathematical models allows you to record, analyze, and predict most of the regularities of the surrounding world.

One of the most complete and powerful system identification methods available today for the identification of both linear and nonlinear systems is the NARMAX approach.

This work described the problems of short-term forecasting of air pollution and the forecasting algorithm based on the NARMAX method. A discrete mathematical model was also described, for which it was necessary to build a short-term forecasting algorithm, the first stage of which is the estimation of the model parameters and their forecasting using the NARMAX method, and the second stage is the construction of a short-term gasification forecast based on the forecasted parameters. As a result, these algorithms were implemented in software and their effectiveness was checked on air pollution data of Kyiv.

Acknowledgements. This work has been supported by Ministry of Education and Science of Ukraine: R&D Project 0122U001844 for the period of 2022-2024 at Taras Shevchenko National University of Kyiv.

Reference

1. Ivanov S.M., Subotina A.H. (2022). Prediction of the level of CO2 in Kyiv based on the NARMAX model. XXXVII International Conference PROBLEMS OF DECISION MAKING UNDER UNCERTAINTIES (PDMU-2022), November 23 - 25, 2022, Sheki-Lankaran, Republic of Azerbaijan. – P. 55.
2. Nakonechnyi A. G., Zinko P. N., Shevchuk Y. M. (2018). Guaranteed Estimation of Nonstationary Parameters of Difference Equations under Uncertainty. Journal of Automation and Information Sciences, 50(11).

ELIMINATION OF QUANTIFIERS IN LOGICS OF PARTIAL NON-MONOTONIC QUASIARY PREDICATES

O. S. Shkilniak, S. S. Shkilniak
Taras Shevchenko National University of Kyiv, Ukraine
oksana.sh@knu.ua, ss.sh@knu.ua

Logical systems can be effectively used for various tasks in computer science and artificial intelligence. However, classical logic of predicates, on which they are usually based, does not adequately take into account the incompleteness, partiality, ambiguity of information about the subject area. This motivates the task of building new, computer science-oriented logics. Such are program-oriented logics of partial quasiary predicates. First-order logics of quasiary predicates will be called L^Q.

Elimination of quantifiers is a typical part of deduction in first-order sequent calculi. In our case, from sequent forms with formulas of the form $\exists x\Phi$ we come to equivalent forms with formulas of the form $R_z^x(\Phi)$. For the logics of non-monotonic predicates, the condition of definedness of z is needed meaning a component with the name z has a value in the input data. Special predicates-indicators will check this condition in L^Q. We can consider total predicates-indicators Ez which can distinguish either the subject variable z *has* an assigned value or *not*, and partial predicates-indicators $\downarrow z$ which can only signal *when* such a component exists. L^Q with predicates-indicators Ez were studied in [1], let us call them $L_{\mathrm{I}}{}^Q$. In this paper we propose L^Q with predicates-indicators $\downarrow z$, let us call them $L_{\downarrow}{}^Q$. L^Q with strong equality predicates use [2] Ez, let us call them $L^{Q\equiv}$. L^Q with weak equality predicates will be called $L^{Q=}$. It turns out $L^{Q=}$ don't need separate predicates-indicators, as $=_{zz}$ plays the role of $\downarrow z$. In this paper we describe semantic properties of $L_{\downarrow}{}^Q$ and $L^{Q=}$, in particular, properties of quantifier elimination with the use of $\downarrow z$ and $=_{zz}$. Also, calculi of sequent type are proposed for these logics.

References

1. Nikitchenko M., Shkilniak O., Shkilniak S. Pure First-Order Logics of Quasiary Predicates // Problems in Programming. – 2016. – Vol.2–3. – P. 73–86 (in Ukrainian).
2. Shkilniak S. First-Order Composition Nominative Logics with Predicates of Weak Equality and of Strong Equality. // Problems in Programming. – 2019. – Vol. 3. – P. 28–44 (in Ukrainian).

SEQUENT DEDUCTION SYSTEMS IN TRANSITIONAL MODAL LOGICS OF PARTIAL PREDICATES

O. S. Shkilniak, S. S. Shkilniak
Taras Shevchenko National University of Kyiv, Ukraine
oksana.sh@knu.ua, ss.sh@knu.ua

Modal logics are used with great success to describe and model information and program systems, artificial intelligence systems (see [1]). Modal logics of partial predicates is a logical formalism which combines capabilities of modal logics of partial predicates and program-oriented logics of partial quasiary predicates. Transitional modal logics (TML) are their important class; they reflect the aspect of change and evolution of subject areas. Semantic properties of TML are described in [2].

Calculi of sequent type can be a powerful deduction tool [2]. In modal logics, such calculi formalize logical consequence relations on sets of formulas specified with states. For TML, we introduce the relations of irrefutability (*IR*), truth (*T*), falsity (*F*), and strong (*TF*) logical consequence.

Pure first-order TML of non-monotonic partial predicates are called TML^{Q}; TML^{Q} with predicates of strong equality $\equiv_{xy}$ are called $\mathrm{TML}^{Q\equiv}$; TML^{Q} with predicates of weak equality $=_{xy}$ are called $\mathrm{TML}^{Q=}$. In this paper we propose sequent calculi for these classes of TML (see also [3]). For logical consequence relations on sets of formulas of types *IR*, *T*, *F* and *TF*, we obtain the following corresponding calculi for TML and $\mathrm{TML}^{Q\equiv}$: Cm^{QIR}, Cm^{QT}, Cm^{QF}, Cm^{QTF}, and $Cm^{QIR\equiv}$, $Cm^{QR\equiv}$, $Cm^{QF\equiv}$, $Cm^{QTF\equiv}$, respectively. For $\mathrm{TML}^{Q=}$, *T*-, *F*- and *TF*-consequences are incorrect, thus only $Cm^{QIR=}$ calculus can be specified. For the introduced calculi, we describe basic sequent forms and closedness conditions for sequents; the soundness and completeness theorems are proved.

References

1. S. Abramsky, D.M. Gabbay, and T.S.E. Maibaum (eds), Handbook of Logic in Computer Science, Vol. 1–5, Oxford University Press, 1993–2000.
2. O. Shkilniak, Modal Logics of Partial Predicates without Monotonicity Restriction, Workshop on Foundations of Informatics: Proceedings FOI-2015, August 24–29, 2015, Chisinau, Moldova, pp. 198–211.
3. O. Shkilniak, S. Shkilniak, First-Order Sequent Calculi of Logics of Quasiary Predicates with Extended Renominations and Equality, Proc. of

the UkrPROGP′2022, Kyiv, Ukraine, October 11–12, 2022. – CEUR Workshop Proceedings (CEUR-WS.org), 2023, pp. 3–18.

BRANCHING OF SOULTIONS IN THE SYSTEM OF KINETIC REACTIONS

I. Sihaiev
Taras Shevchenko National University of Kyiv, Ukraine
igor.sigaev@gmail.com

The report is devoted to obtaining branching of solutions conditions for the following boundary-value problem

$$\begin{cases} X'(t,\varepsilon) = -(B+1)X(t,\varepsilon) + \varepsilon X^2(t,\varepsilon)Y(t,\varepsilon) + A(t), \\ Y'(t,\varepsilon) = BX(t,\varepsilon) - \varepsilon X^2(t,\varepsilon)Y(t,\varepsilon) + D(t), \end{cases} \quad (1)$$

With general boundary conditions in the following form

$$l\begin{pmatrix} X(\cdot,\varepsilon) \\ Y(\cdot,\varepsilon) \end{pmatrix} = \alpha,$$

where linear functional l translates solutions $X(\cdot,\varepsilon), Y(\cdot,\varepsilon)$ of (1) into the finite-dimensional space R^m, $\alpha \in R^m$. (1) is the well-known brucellator model [1, p.189], $X(\cdot,\varepsilon)$, $Y(\cdot,\varepsilon)$ are corresponding concentrations of components. We investigate such model with using of the theory constructed in [2-4] in the critical case.

References

1.Boichuk O.A., Pokutnyi O.O. Normally resolvable boundary-value problems for the operator-differential equations. – Kyiv, Naukova dumka, 2022. – 222 p. (in Ukrainian). doi.org/10.37863/2843457491-61.
2. Boichuk O.A., Pokutnyi O.O. Perturbation theory of operator equations in the Frechet and Hilbert spaces // Ukrains'kyi Matematychnyi Zhurnal. – 2016. – No.9. – P.1327-1335. doi: 10.1007/s11253-016-1156-y.
3. Boichuk O.A., Pokutnyi O.O. Solutions of the Schrodinger equation in a Hilbert space. // Boundary Value problems. – 2014. – Vol. 4. doi: 10.1186/1687-2770-2014-4.
4. Panasenko E.V., Pokutnyi O.O. Boundary-value problems for the Lyapunov equation in Banach spaces // Journal of mathematical sciences. – 2017. – Vol. 3. – P. 298-304. doi: 10.1007/s10958-017-3356-x.

MEANS OF DECODING CONVERSION CODES IN CONTROL SYSTEMS AND SPECIAL PURPOSE EQUIPMENT

K. Sosnenko, T. Samoliuk
Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine
sosnenko.kate@ukr.net, tamara.samoliuk@ukr.net

Software and hardware decoding tools for convolutional codes in control systems and special-purpose hardware designed for semi-realistic simulation of embedded systems using IoT and wireless sensor networks have been developed.

A method of using the Viterbi algorithm for error correction at high signal transmission speed in systems using IoT and wireless sensor networks has been developed.

The work uses convolutional codes in data transmission for embedded IoT systems as interference-resistant coding schemes. The popularity of these codes is due to the possibility of their decoding using the Viterbi algorithm, which provides optimal decoding according to the criteria of maximum likelihood with a relatively small (compared to other classes of codes) computational complexity.

In an embedded IoT system, four critical components come together to create a single functional unit: hardware, software, operating system (OS), and user interface.

The hardware components that make up an embedded IoT system include microcontrollers, sensors, actuators, communication interfaces (Wi-Fi, Bluetooth, etc.), power management circuits, and any additional peripherals required for a particular application. While traditional embedded systems manage data locally, IoT embedded systems connect to online cloud services. Wireless sensor networks such as Wi-Fi, Bluetooth, 5G and LoRa play a key role in unlocking the great potential of embedded IoT systems.

An embedded OS or RTOS (real-time operating system) manages tasks, scheduling, and resource allocation, allowing multiple processes to run efficiently and maintaining responsiveness, especially in real-time or multitasking scenarios.

Software controls hardware behavior and provides data processing, communication, and decision-making. This includes firmware on microcontrollers, device drivers for sensors and actuators, communication protocols, and application-specific software logic.

THE PROBLEM OF AGGREGATION, PROCESSING AND ANALYSIS OF INTERNET TRAFFIC

I. Stetsenko, Y. Tretiakov, I. Vergunova
Taras Shevchenko National University of Kyiv, Ukraine
illiastetsenko@knu.ua, egorken3v@knu.ua,
iryna.vergunova@knu.ua

The growing number of various devices connected to the Internet is becoming more and more common for each user. And the issue of stability and security becomes even more urgent. Therefore, it is often important for users to know the exact nature of the traffic passing through their devices. Much attention has always been paid to the solution of the problem of aggregation and processing of Internet traffic, but even today there are no free, freely distributed system solutions that provide a convenient, understandable, easy-to-use user interface for everyday use.

The work offers a system solution aimed at solving this problem and is built on the basis of a comparative analysis of common methods of solving the problem of aggregation and Internet traffic analysis. It aimed to implement its own system of aggregation (the NetStalker project), processing and analysis of Internet traffic, easy to use and with a convenient interface.

The work used a software approach to collecting Internet traffic, and it was understood that the analyzer can receive information from many aggregators, and therefore the application for aggregation was built independent of the analysis system. It was concluded that the collected traffic should be stored on the media in the pcap format, the application should intercept the data in a passive format, so that in case of long traffic aggregation, we do not intercept the Internet traffic created by ourselves.

To perform traffic analysis, a microservice architecture web application is developed that is independent of the aggregation application and equally accessible to all aggregators. The application for processing and analyzing traffic was based on the unification of the behavior of applications within the system (with the developed core project – Net-core).

The traffic aggregation application (NetAgent) has an Agent component to implement the packet aggregation logic using the Poller packet capture framework (helps to aggregate a certain number of packets and save them to disk in pcap format).

To process Internet traffic, the server and client parts of the

corresponding application are implemented, and the issue of communication between these parts is also considered. Since the server and client parts of the application are developed using different technologies and are independent (the client part has no information about what is happening in the server part, it only uses the Application Programming Interface (API) provided by the server), the Representational State Transfer (REST) approach was used. It provides for the following restrictions: Resource Identification, Uniform Interface, Self-Describing Messages, Hypermedia Driving Application State, Stateless Interactions.

To meet these requirements, the server part of the web application was divided into two independent parts: a part for processing and managing pcap files and a part for supporting interaction with the client in RESTful format and data transfer in JSON format. Communication between these parts is implemented using the Quick UDP Internet Connections (QUIC) protocol.

Since communication between services must take place in a standard format, it was decided to transfer the same Envelope structures (Net-core project) between them, which were built as a wrapper around the API of the structure being transferred, and as a carrier of its representation encoded in binary format together with a unique identifier of the structure.

A special database was used to save Internet traffic aggregated by the user.

Microservices were also implemented in the system: net-gateway – for communication in RESTful format with the client; net-timescale – for communication with the database, as well as for processing user requests.

The database interaction service has the following components: net-reporter – for preparing data for display to the client; net-inserter – for uploading data to the aggregated Internet traffic database; net-updater – is responsible for processing requests to change data about aggregated Internet traffic from the database and for updating materialized views.

The implemented solution, consisting of an Internet traffic aggregation application and a web application for processing, reviewing and analyzing Internet traffic, due to its ease of use, the provided set of options and efficiency, allows each user to get a detailed understanding of what is happening with his Internet traffic.

APPLICATION OF BAYESIAN INFERENCE IN OPTIMIZATION PROBLEMS WITH UNKNOWN OBJECTIVE FUNCTION PARAMETERS

A.V. Stopchatyi
Taras Shevchenko National University of Kyiv, Ukraine
astopchatyy@gmail.com

An optimization problem is considered where the objective function depends not only on the optimization variable but also on a parameter vector, the values of which are unknown.

Let $g(\boldsymbol{x}, \boldsymbol{\alpha})$ be an objective function. Here $\boldsymbol{x} \in \mathbb{R}^n$ is an optimization variable and $\boldsymbol{\alpha} \in \mathbb{R}^m$ is a vector of unknown parameters of objective function, both constrained by systems of equations and inequalities.

Let y be a random variable observed at point $\boldsymbol{x}$, with its distribution depending on the value of the objective function $g(\boldsymbol{x}, \boldsymbol{\alpha})$ at this point.

The problem then consists in finding an approximate solution $\tilde{x}$ that maximizes (or minimizes) the objective function, given that for a certain set of points $x_i, i = 1, \dots t$ there are known samples of observations $y_{i,j}, j = 1, \dots t_i$.

The approach considered in the work is to find at first the estimate of the vector of unknown parameters using methods based on Bayesian inference, and then solve the optimization problem using the found estimate as parameters of the objective function.

References

1. Borek Puza. Bayesian methods for statistical analysis - ANU eView/ 2015. – ISBN 978-1-9219-3426-1 (ebook)
2. Moklyachuk M. P. Fundamentals of convex analysis. Study guide. – Kyiv, TViMS Publishing House, 2004.

CONTROL PROBLEMS OF DYNAMICS OF THICK ELASTIC PLATES WITH A CONTINUOUSLY SPECIFIED DESIRED CONDITION

Volodymyr Stoyan, Serhii Voloshchuk
Taras Shevchenko National University of Kyiv, Kyiv, Ukraine
v_a_stoyan@ukr.net, sr.voloshchuk@gmail.com

The dynamic model of a three-dimensional elastic plate of the cylindrical shape with a curvilinear lateral surface is considered. It is believed that the displacement of the plate points $u(s) =$

$col(u_x(s), u_y(s), u_z(s))$, $s = (x, y, z, t)$ relative to the coordinate axes occurs under the action of force $f(s) = \big(f_1(s), f_2(s), f_3(s)\big)^T$ and satisfies the equation of Lamé [1]

$$L(\partial_s)u(s) = f(s),\ \partial_s = (\partial_s, \partial_y, \partial_z, \partial_t).$$

With known initial, boundary, and surface conditions, the function of plate point displacements can be expressed as a sum [2]

$$u(s) = u_\infty(s) + u^0(s) + u^\Gamma(s) + u^+(s) + u^-(s)\,.$$

For the specified model of the elastic plate, which is under the action of voluminous $f(s)$, initial $f^0(s)$, boundary $f^\Gamma(s)$ and surface $f^\pm(s)$ external dynamic disturbing factors, the problems of controlling her condition are set and solved. One or more of the above factors are considered to be controlling. Let's determine them from the existing initial, boundary, surface and desirable states of the plate given by continuous functions. One can find control after mean-square solution of the functional equation system [3]

$$B(s)\bar{\bar{f}} = U(s),$$

where $\bar{\bar{f}} = col\big(\bar{f}^0, \bar{f}^+, \bar{f}^-, \bar{f}^\Gamma, \bar{f}\big)$, $U(s)$ – vector function of the right-hand sides of all given initial, boundary, surface, and desired conditions, $B(s)$ – block matrix function, which contains functions with unknown components of the control vector $\bar{f}$ and modeling vectors $\bar{f}^0, \bar{f}^\Gamma, \bar{f}^\pm$. Unambiguity and root-mean-square accuracy of control results are estimated.

References

1. Lure A. Spatial problems of elasticity theory. – M.: Gostekhizdat, 1955. – 492 p.

2. Stoyan V., Voloshchuk S. On three-dimensional problems of dynamics of thick elastic plates // International Scientific Technical Journal" Problems of Control and Informatics". – 2021. – № 3. – P. 34-49.

3. Stoyan V. Mathematical modeling of the dynamics of incompletely observed linear spatially distributed systems: Monograph. - K.: "Kyiv University", 2019. - 318 p.

COVID-19 COMPUTED TOMOGRAPHY IMAGE PROCESSING BASED ON STATISTICAL SEGMENTATION METHODS

V.I. Suchkov, A.O. Pashko
Taras Shevchenko National University of Kyiv, Ukraine
valentynsuchkov@gmail.com, aap2011@ukr.net

Monitoring the state of the respiratory tract during the disease caused by COVID-19 is an important aspect in the treatment of patients and control of their general condition. Chest computed tomography (CT) is an effective screening method for COVID-19 because of its high sensitivity.

The “ground glass opacity” area of the lung in computed tomography (CT) images is one of the main features of COVID-19 [1]. Automating the image analysis process will help improve the accuracy of patient condition indicators and diagnostics. The use of computer vision methods allows to determine the signs of diseases in the early stages of the disease for rapid treatment.

One of the main processes of image processing and analysis is segmentation, which solves the problem of highlighting one area of the image against the background of another. Deep learning is widely used to segment “ground glass opacity” regions. However, statistical methods of image analysis can implement a much faster segmentation and do not require extensive training and calculations [2].

The article considers the application of statistical methods of image segmentation to solve the problem of localization "ground glass opacity" infected regions in the input image. The proposed mechanism based on the thresholding, which separates the area of interest from background artifacts. After that, the k-means clustering algorithm is used to classify the pixels and localize the infected segments. The ratio between the pixels of the infected and lung segments is considered to determine the severity of infection.

References

1. Kanne J. P. et al. COVID-19 imaging: What we know now and what remains unknown. // Radiology. – 2021. – Vol. 299. – E262–E279.
2. Rao Y, Lv Q, Zeng S, Yi Y, Huang C, Gao Y, Cheng Z, Sun J. COVID-19 CT ground-glass opacity segmentation based on attention mechanism threshold.// Biomed Signal Process Control. – 2023. – Vol.81. – 104486.
3. Venkatesan Rajinikanth et al. Harmony-search and otsu based system for coronavirus disease (COVID-19) detection using lung CT scan images// arXiv, 2020, arXiv:2004.03431.

HYBRID METHODS FOR MODELING KNOWLEDGE-BASED SYSTEMS USING PNES

Z. Suraj, P. Grochowalski, P. Drygaś
University of Rzeszów, Poland
{zsuraj, pgrochowalski, padrygaś}@ur.edu.pl

In many fields of science, the phenomena and objects under study are often not studied directly, but indirectly, through the analysis of special models. These models are a specific representation, often expressed in mathematical terms and symbols, that highlights important features and properties of the objects under study. Operating representations guarantees economic development of knowledge about the phenomena being modeled.

The development of IT tools has expanded the applications of system modeling. By representing systems in the form of mathematical models and performing specific operations on them using appropriate computer tools, we can construct larger and more complex system models. And this, in turn, influenced the increasingly faster and broader development of research on computer modeling techniques.

Petri nets are a useful formal tool for modeling and analyzing concurrent systems, including systems operating in uncertain environments [1]. The basic limitations of Petri net applications result from the fact that net models of real systems are generally very complex, and both their correct construction and efficient analysis are in practice only possible when appropriate tools are available that automatically perform these activities.

For some time now, there has been a clear interest in creating computer programs for Petri nets. Rich and convenient software should help the user of Petri nets in performing many detailed activities when constructing models of complex real systems and examining their properties.

The aim of the lecture is to present selected methods of modeling and analysis of knowledge-based systems implemented in the Petri Net System (PNeS), designed and developed since 2011 at the University of Rzeszów [2]. This system constitutes a specific research platform for experimental verification of the proposed methods and algorithms in the field of research [3].

References

1. The Petri Nets World. https://www.informatik.uni-hamburg.de/TGI/PetriNets/index.php

2. Suraj, Z., Grochowalski, P.: PNeS in Modelling, Control and Analysis of Concurrent Systems. Lect. Notes in Artif. Intell. 12872, pp. 279-309, Springer Nature, 2021.
3. Suraj, Z., Grochowalski, P., Drygaś, P.: Automated Discovery of Concurrent Models of Decision-Making Systems from Data. Lect. Notes in Comp. Sci., Vol. 14833, Springer, 2024.

AUTOMATIC STRUCTURING AND ANALYSIS OF PHYSICAL ADDRESSES USING BERT MODEL

D. Taraniuk, M. Makhno
Taras Shevchenko National University of Kyiv Ukraine, Ukraine
taranykdm@gmail.com

The evolution of massive volumes of unstructured data has emerged as one of the key challenges for information handling in this present digital era. Among the various categories, physical addresses hold a prime position due to their inconsistent format issues that pose a challenge for manual processing. The research has proposed an end-to-end automated system that can structure physical addresses which is developed with a blend of Artificial Intelligence techniques. Central to this system are transformers, a powerful AI architecture known for their ability to handle sequential data effectively [1], with BERT (Bidirectional Encoder Representations from Transformers) playing the lead role and helping to overcome these challenges [2].

The main goal of this study is to develop a system that can split addresses into parts like country, city, street and house number. It achieves high accuracy in identifying and standardizing address data by the use of neural networks plus the BERT model; which would be very instrumental in streamlining the data operation systems among governmental registers, commercial enterprises and other bodies.

The approach is training the BERT model using a collection of more than 300,000 already classified addresses. This consists of data preparation, which involves identifying address components, cleaning, and normalizing the data [3]. The next stage includes model training and validation, where the data is split into training and validation sets [4]. The outcome shows the model’s capacity to reach around 70-75% accuracy on the correct classification of address elements, indicating a promising solution for real-world use cases in different data systems.

The study is in line with the world's current AI wave — used for huge

data processing. It brings about big leaps in the precision and effectiveness of address data management. The system can find use in state registers, marketing companies; take a step back and observe its broad reach and how important it is to today's information-focused world.

References

1. Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N. Gomez, Łukasz Kaiser, Illia Polosukhin. Attention Is All You Need. Proceedings of the 31st International Conference on Neural Information Processing Systems. – 2017. – P. 2-9.
2. Rani Horev. BERT Explained: State of the art language model for NLP. // Towards Data Science, 2018.
3. Diego Lopez Yse. Text Normalization for Natural Language Processing (NLP). // Towards Data Science, 2021.
4. Sagar Sharma. Epoch vs Batch Size vs Iterations. // Towards Data Science, 2017.

MODERN MOBILE MEDICAL AND DIAGNOSTIC COMPLEXES

E. Timashov
Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine
busurmanin@gmail.com

Mobile medical and diagnostic complexes are modern solutions for providing medical services in remote or hard-to-reach areas. They are equipped with the necessary equipment for conducting various medical examinations and procedures, providing quick access to quality medical care.

The main advantages of mobile medical and diagnostic complexes:

They are easy to move and can quickly reach any location; These include ultrasound machines, X-ray units, laboratory equipment and others; Can work without connecting to external power sources, which is especially important for work in remote areas; Provide quick examination and diagnosis of patients on the spot. Such complexes are used in various fields of medicine, including cardiology, gynecology, pediatrics, and many others. They can be extremely useful during emergencies, military operations, or in cases of natural disasters.

The introduction of mobile medical and diagnostic complexes contributes to increasing the level of medical care and the availability of medical services for the population, especially in remote regions.

In addition to the main advantages, mobile medical and diagnostic

complexes can have additional functions and capabilities that make them even more useful and versatile:

1. Telemedicine: Thanks to modern technologies, complexes can be equipped with telemedicine systems, which allows consultations with specialists located in remote medical centers or hospitals. This is especially useful for diagnosing complex cases and making operational decisions.

2. Flexibility in settings: Complexes can be configured according to the needs of a specific region or the type of medical services to be provided. For example, one complex may be specialized in the diagnosis of cardiovascular diseases, while another is specialized in providing care to pregnant women.

3. Rapid deployment: Mobile complexes can be rapidly deployed and prepared for operation within a short time, which is a decisive factor in cases of emergencies or epidemics.

4. Training and professional development: educational programs and trainings for medical personnel can be held on the basis of mobile complexes, which contributes to improving their qualifications and awareness of new medical technologies and treatment methods.

ANALYSIS OF THE INTERVALS BETWEEN TRAINS AT A SUBWAY STATION USING QUEUEING MODELLING

Mariia Tkach
Taras Shevchenko National University of Kyiv, Ukraine
mashatkach@knu.ua

The main goal of the work is to find the most optimal interval between train movements by studying the passenger flow at the metro station and using the tools of queueing theory. This problem has a practical application in real life and greatly affects the efficiency of passenger movement.

Solving the problem was based on the model of tandem queues. One of the queueing systems in the tandem is the station itself, and another is the checkpoints. Providing such a model unable us solve a lot of problems. In particular, we can calculate the optimal number of devices at the subway checkpoints, so that with this minimum number, the queue of passengers would not accumulate. That is, to make passenger service comfortable.

Since an existing metro station already has a set number of validators, we were able to compare how the overall experience of staying at the station would change by simulating the flow of passengers with different numbers of devices using the R programming language.

Next, by finding the interval between trains, we obtain an interval such that the number of passengers, who will arrive at the station within it, does not exceed the average number of people that can comfortably fit on the train

References

1. Ng Chee-Hock, Soong Boon-Hee. Queueing Modelling Fundamentals With Applications in Communication Networks. Second Edition. – John Wiley and Sons, 2008. – 294 p.

2. Shaokuan Chen, Yue Di, Shuang Liu, Baoshan Wang. Modelling and Analysis on Emergency Evacuation from Metro Stations // Mathematical Problems in Engineering. – 2017. – P. 1-11. https://doi.org/10.1155/2017/2623684

3. Sai Li, Xiukun Wei, Zhe Zhang, Limin Jia, Junyan Yu. Subway Station Capacity Maintained by Optimizing a Maintenance Schedule of Key Equipment // Appl. Sci. – 2019. – Vol. 9(7). – 1386. https://doi.org/10.3390/app9071386

A NON-ABELIAN GROUP OF CONGRUENT NUMBERS

Ruslan Tsinaridze

Batumi Shota Rustaveli State University, Georgia

One of the oldest problems is the Congruent Numbers Problem. An n-natural number is called a congruent number if there is a right triangle with rational sides whose area is equal to n. This problem is related to elliptical curve. The following theorem is true: an n-natural number is congruent if and only if the elliptic curve $y^2 = x^3 - n^2 x$ has a non-trivial rational solution.

The following results are obtained: an algebraic operation is defined on sets of all congruent numbers; It is shown that this operation define a non-abelian group; The connection between this group and the 3-dimensional Special Linear group $Sl(3;Z)$ is established; In particular, it is shown that the non-abelian group of all congruent numbers is a subgroup of the 3-dimensional Special linear group.

References

1. Wiles A. The Birch and Swinnerton-Dyer conjecture, https://www.claymath.org/wp-content/uploads/2022/05/birchswin.pdf

2. Tunnell J. A Classical Diophantine Problem and Modular Forms of Weight 3/2. – Invent. Math. – 1983. – Vol. 72. – P. 323-334.

3. Coates J., Wiles A. On the conjecture of Birch and Swinnerton-Dyer// Invent. Math. – 1977. – Vol.39. – P.223-252.
4. Conrad K. The congruent number problem, www.math.uconn.edu/~kconrad/ blurbs/ugradnumthy/congnumber.pdf, [Online; accessed 2-4 2018].

SPATIAL MEMORY IMPAIRMENT IN MEDIAL SEPTAL AND DENTATE GYRUS LESIONED RATS

I. Tsintsadze[1], T. Asanidze[1], N. Chkhikvishvili[2]
[1]Batumi Shota Rustaveli State University, Georgia
[2]Ivane Beritashvilis eksperimentuli biomeditsinis tsentri, Georgia

The aim of the present study was to investigate the modulation of the hippocampal function by cortical and subcortical inputs and was designed to investigate the role of the medial septal nucleus (MS) and dentate gyrus (DG) in learning and memory using the neurotoxin (ibotenic acid) to produce lesions of these structures. Rats received bilateral infusions (0.2 μl per side, 0,05 μl/min) into the DG and infusions into the MS at two positions (0,2 and 0,3 μl; 0,05 μl/min).

The ability of sham-operated, MS and DG lesioned rats to learn the location of a visible, as well as submerged platform in a water maze, was studied in these experiments. A total of 24 male rats were used in the study. In conditions of vissible platform testing, differences in the platform reaching latency between the animals of different groups were not found. At the days 3, 6, 9 when testing was performed in conditions of submerged platform, the latency of the platform finding of the DG-lesioned rats was significantly increased ($P<0.05$). This fact certifies for deficit of the place learning performance strategy in the DG-lesioned rats.

The rats' responses in the competition test were classified either as cue or as place, based on the swimming path for those trials. Decreased place-bias in MS and DG-lesioned rats compared to the sham-operated rats was significant (MS - $t_d = 2{,}54$; DG - $t_d = 2$; $P<0.02$). The data obtained demonstrate that the MS and DG-lesioned rats acquired the visible platform version of the water maze task but failed to learn the platform location in space. These findings suggest that the MS and DG are essential for accurate spatial learning and suggest their role in processing information about the spatial environment.

WIRELESS SENSOR NETWORKS AND IoT FOR EMBEDDED SYSTEMS

O. Tymashov
Glushkov Institute of Cybernetics NAS of Ukraine
alex_timashov@outlook.com

In an increasingly connected world, the seamless integration of various technologies has become crucial. Among these technologies, Wireless Sensor Networks (WSNs) and the Internet of Things (IoT) have emerged as transformative forces. WSNs consist of spatially distributed autonomous sensors that monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion, or pollutants. The sensors communicate wirelessly and cooperatively to relay data to a central location, enabling comprehensive monitoring and analysis.

The IoT, on the other hand, extends internet connectivity beyond traditional devices like computers and smartphones to a diverse range of physical devices and everyday objects. This interconnectivity allows for the collection and exchange of data, paving the way for smarter and more efficient systems. The convergence of WSNs and IoT is particularly significant for embedded systems, which are specialized computing systems that perform dedicated functions within larger mechanical or electrical systems.

Embedded systems are integral to the operation of various devices and applications, from household appliances to industrial machinery and medical equipment. By integrating WSNs and IoT, these systems can achieve enhanced functionality, improved performance, and greater reliability.

As technology continues to advance, the future of WSNs and IoT in embedded systems looks promising. Emerging trends such as edge computing, artificial intelligence, and machine learning are poised to further enhance the capabilities of these systems. Edge computing allows for data processing at the source, reducing latency and improving real-time decision-making. Artificial intelligence and machine learning can be applied to sensor data for predictive maintenance, anomaly detection, and adaptive control.

In addition, the development of low-power communication protocols and energy-harvesting technologies will address the energy efficiency challenge. The continued evolution of WSNs and IoT will enable new applications and innovations, driving progress in various fields and contributing to a smarter, more connected world.

SOLVING ARTIFICIAL INTELLIGENCE PROBLEMS USING COMBINATORICS

N.K. Tymofieva
International Research and Training Center for Information Technologies and Systems under NAS and MES of Ukraine
tymnad@gmail.com

Artificial intelligence includes problems related to the recognition of images, sound signals, etc. Signals of various nature (speech, electrocardiograms, electroencephalograms) are specified by combinatorial configurations of a certain type [1].

The electrocardiogram is described by placement with repetitions and in the problem of recognition they act as input data. Processing of this signal is carried out in order to segment it to establish the frequency of heart contractions, the duration of the systole and diastole periods, and the values of the amplitudes of the prongs P, Q, R, S, T, U. Segmentation of electrocardiograms is carried out in several iterations, which allows to achieve high accuracy of solving the problem with a small expenditure of machine time. As a result, the length of the current almost period, which corresponds to the total duration of systole and diastole, and the frequency of heart contractions, is determined by the selected almost periodic sections of the electrocardiogram.

To recognize multi-speaker speech, the speech signal (placement with repetitions) is given by the sequence $f|_1^n = (f_1, f_2, ..., f_n)$, where f_j the value of the amplitude in counting j of the signal. We will segment it into almost periodic and non-periodic segments. The current almost period is divided into k counts and described by a multiset, which is set by the base $(f|_1^k, m)$, where k is a value that is determined experimentally and must be the same for any segment of the signal. The etalon, by which the similarity of the almost period is established, is modeled similarly. Similarity is determined by the expression $\left|f_l - f_l^{'}\right| \le \varepsilon$ and $\left|m_l - m_l^{'}\right| \le \varepsilon^{'}$, where $f_l^{'}$ is the value of the signal of etalon in counting l, $m_l^{'}$ – is the multiplicity of the element $f_l^{'}$, ε, $\varepsilon^{'}$ are the minimum values by which the similarity of the input and etalon signals is established.

References

1. Tymofijeva N.K. Some Ways to Modeling Input Data for Information Search in the Library of Standards when Solving Semantics Problems// //

Journal of Automation and Information Sciences. – 2020. – Vol.6. – P. 16–28.

MISUSE OF ARTIFICIAL INTELLIGENCE FOR CYBER ATTACKS AND COUNTERS DATA ATTACKS IN MODERN INFORMATION SYSTEMS

Y. Tupalo
Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine
Typaloyaroslav91@gmail.com

The use of artificial intelligence in cyber security is becoming more and more relevant, especially in the context of countering phishing attacks. Artificial intelligence can help automate the process of detecting phishing attacks, but it cannot replace basic security measures such as secure coding and user education. Using machine learning to analyze user behavior and identify unusual patterns can be an effective means of detecting phishing attacks. However, it also requires a lot of data and resources to train and tune the models. Secure coding, such as cleaning sensitive data when it is no longer needed is also an element of protection against phishing attacks. This can help reduce popular losses if a phishing attack does successfully compromise a user's session. Overall, artificial intelligence and machine learning can play an important role in countering phishing attacks. However, they should be used in combination with other protection methods, including secure coding and user education. It is important to remember that no matter how effective artificial intelligence technologies are, they cannot replace the human factor. Educating users about potential phishing risks and how to deal with them avoidance is an important part of an overall defense strategy.

MODELING THE MOVEMENT OF ELEMENTS WITH MEMORY IN AN ACTIVE ENVIRONMENT

O. Vasyliev
Taras Shevchenko National University of Kyiv, Ukraine
vasilev@knu.ua

The research is focused on a system with moving elements that have simple behavior algorithms, making them capable of performing local system analysis. An example of such a situation is chemotaxis when

bacteria of a certain type moving in an active environment can register the local concentration of a special active substance (called attractant) [1]. Numerous experimental studies demonstrate that in such a system, the bacteria are redistributed following the distribution of the attractant concentration in the system [2]. At the same time, the size of the bacterium is too small to track the direction of a significant change in the attractant concentration by registering the attractant concentration with different receptors. In other words, the concentration of the attractant is measured locally [2,3]. Nevertheless, the algorithm of movement helps bacteria to find areas with high attractant concentrations. Namely, most of the time, the bacterium moves straightly with a constant speed. But at certain moments, it stops and randomly changes the direction. This process is called tumbling. The tumbling frequency depends on how much attractant the bacterium has registered while moving through the system. The higher the total concentration registered by the bacterium, the lower the tumbling frequency. As a result, being in an area with a high concentration of the attractant, the bacterium reduces the frequency of tumbling, which reduces the probability of changing the direction of the bacterium's movement [2,3].

We investigate the algorithm allowing bacteria to follow the attractant distribution. The main problem here is related to the complexity of the chain of interactions involved in implementing bacterial behavior [3,4]. We analyze the algorithm's key features and make some modulations to test its effectiveness.

References

1. J. Adler. Chemotaxis in bacteria // Science. – 1966. – 153. – P. 708.
2. T. Namba, M. Nishikawa, T. Shibata. The Relation of Signal Transduction to the Sensitivity and Dynamic Range of Bacterial Chemotaxis // Biophysical Journal. – 2012. – 103. – P. 1390.
3. J.D. Murray. Mathematical Biology: I. An Introduction. New York / Springer, 2007.
4. A.N. Vasilev. Analytical Approach for Calculating the Chemotaxis Sensitivity Function // Ukrainian Journal of Physics. – 2018. – 63. – P. 255.

ONE METHOD FOR ESTIMATING POPULATION DISPLACEMENT

R. Vavryk, Y. Sokolovskyy
Lviv Polytechnic National University, Ukraine
roman.r.vavryk@lpnu.ua, yaroslav.i.sokolovskyi@lpnu.ua

The ongoing Russian invasion of Ukraine has caused one of the biggest humanitarian crises in recent history, specifically in terms of both internal and international displacement of the Ukrainian population [1]. Traditional population tracking methods mostly rely on census data, government reports, and surveys, which face substantial challenges in this context. As people migrate to various countries and continue to change their place of residence, synchronizing data across different countries becomes increasingly difficult. Additionally, traditional methods fail to identify emerging patterns of further displacement [2].

In this paper, we propose a method for estimating population displacement based on public data from platforms like Google Maps, optimized for detecting time-sensitive migration patterns to support decision-making for humanitarian aid, resource allocation, and government policy response.

The proposed method synthesizes a network of displacement connections and requires the following steps:

1. Identification of key locations: the most likely places to be visited by displaced people in the target countries.
2. Detection of displaced individuals: among recent reviews by examining user profiles, names, and review content, labeling their previous "centers of interest".
3. Network synthesis: aggregation of the identified people-places connections into a network where nodes represent cities, and edges represent the number of displaced people.

The final network visualizes population displacement and is then used as input for an Agent-Based Population model which further analyzes migration patterns.

References

1. Refugees from Ukraine in the EU. European Council. (n.d.). https://www.consilium.europa.eu/en/infographics/ukraine-refugees-eu/.
2. Ukrainians leaving Poland for Germany as Europe cries out for workers. https://www.euronews.com/business/2023/09/12/ukrainians-leaving-poland-for-germany-as-europe-cries-out-for-workers.

SOME ALGORITHMS OF VECTOR PROGNOSTICATION

O. Voina
Taras Shevchenko National University of Kyiv, Ukraine
avoina@hotmail.com

There is a concept of vector (or agreed) prognosis in the practice of econometric forecasting. This is connected with the existence of certain conditions of internal (balanced) consistency of exogenous variables of the model. One of the ways to obtain a compatible prognosis is to build a vector prognostication model. In other words, it is necessary to determine the estimates of its parameters in such a way that the conditions of internal consistency are fulfilled automatically. In the study this approach is illustrated on the example of a vector economic-mathematical model that describes the amount of financing of individual divisions of the economic system:

$$s_m = f_m(S, \xi_m),\ m = 1, 2, \ldots, M,\ s_1 + s_2 + \ldots + s_M = S.$$

Functions $f_m(S, \xi_m)$, $m = 1, 2, \ldots, M$, determine the amount of funding depending on the amount (S) of the available asset, $\{\xi_m, m = 1, \ldots, M\}$ is a vector of random variables of the model. In particular, the following example is investigated in detail $M = 3$:

$$f_1(S) = a \cdot S/(S + b);\ f_2(S) = c \cdot (S - d)/(S + e);\ f_3(S) = f \cdot S \cdot (S - g)/(S + h).$$

We assume that for n past time intervals $t \in \{1, 2, \ldots, n\}$, the values of the assets $\{S_1, S_2, \ldots, S_n\}$ that were distributed and the corresponding amounts of financing $[\{s_{t1}, s_{t2}, s_{t3}\},\ t = 1, 2, \ldots, n]$ of individual subdivisions are known. Numerical values $\{Sn + \tau,\ \tau = 1, 2, \ldots, k\}$ assets for k time intervals in the future are also known.

It is necessary to determine forecasts of financing volumes of individual divisions:

$$\hat{s}_{n+\tau(m)} = [\hat{s}_{n+\tau 1}, \hat{s}_{n+\tau 2}, \hat{s}_{n+\tau 3}],\ \tau = 1, 2, \ldots, k,$$

At the same time, the following balance conditions must be met:

$$\hat{s}_{n+\tau 1} + \hat{s}_{n+\tau 2} + \hat{s}_{n+\tau 3} = S_{n+\tau},\ \tau = 1, 2, \ldots, k.$$

It is proved that the agreed prognosis exists if and only if, when the following conditions for the model parameters are met:

$$b = e = h;\ f = 1;\ d = 0;\ a + c - b - g = 0.$$

An explicit view of model parameter estimates was found

$$\hat{a} \approx a;\ \hat{b} \approx b;\ \hat{c} \approx c;\ \hat{g} \approx g$$

on the basis of empirical data $[\{s_{t1}, s_{t2}, s_{t3}\},\ t = 1, 2, \ldots, n]$.

HARDWARE FOR STORING AND PROCESSING A UNIT OF INFORMATION IN MATRIX-ALGEBRAIC COMPUTERS

V.Vyshinskiy, O.Vyshinska, O.Kononenko, A.Slipets, V.Eresko
Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine
vyshinskiy@ukr.net, vyshinskaya@ukr.net, kononenko17@i.ua, alla_volod@ukr.net, fkp500@i.ua

In the development of computer technology, there is a stage where, as a minimum unit of information, not a tiny cluster of information, as in a bit should be used, but rather a more extensive one found in an element of one of the known numerical algebras. That is, not only the algebra of real numbers represented in the binary numeral system, but also in an algebra of the same numbers, which are defined in a numeral system based on the base of three, five, seven, and so on. Moreover, such systems do not necessarily have to be homogeneous, they belong to the multivalued calculation systems. In addition to the systems mentioned, numerical algebras are used, for which complex numbers can be used as a base, and then the consumer deals with hypercomplex numbers and their representation in the corresponding numeral systems, where a complex number is used as a base. It is also known that in computational practice, people use matrix algebras. And then, a very promising development in computer technology is the use of a matrix of fixed size as a machine unit of information over numbers in a fixed numeral system. This development in computer technology is very interesting from the point of view that each of the theses mentioned earlier in this text, algebra, has a regular matrix representation. That is, its elements can be specified by matrices, and machine operations on them are in the same matrix algebra. It follows that by providing efficient storage and operations on such machine data through hardware solutions, the developer of new computer technology will come to an absolutely new generation of electronic computers. These theses consider some examples of hardware support for the storage and processing of numerical matrices used as machine data for matrix-algebraic computers. The prospects for creating hardware devices responsible for the operation of the central processor of a new generation machine are shown.

USE OF THE INTERNET OF THINGS IN THE DEVELOPMENT OF AN INTELLIGENT INTERFACE FOR SEMI-NATURE MODELING SYSTEMS

Y. Yakovliev, L. Kurzantseva
Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine
yakyurlen@ukr.net, larku@ukr.net

An important part of the semi-lifelike simulation system is the experimenter's workplace. Due to the involvement of IoT technologies, such as peripheral and cloud computing, machine learning, ontology, multi-agent technology, the intelligent interface of the experimenter will significantly improve its capabilities and create comfortable conditions for the user. Thanks to peripheral computing, computing power at the periphery of the IoT network increases and communication latency decreases. Cloud technologies require little time for deployment, are used for remote data storage and management of IoT devices, which makes data available to several devices in the network. Machine learning algorithms are used for data processing and real-time decision-making in peripheral and cloud computing technologies. Login to the semi-natural simulation system is performed using biometric authentication, after which the interface sets the optimal configuration of the system for a specific experimenter, and further monitors its condition, launches tools for further analysis of the results, as well as the actions of the experimenter, in critical situations, warns of danger, as well includes intellectual means of support, if necessary, offers help in conducting the experiment. New possibilities of using the IoT will allow several experimenters who may be at different distances from the place of the experiment to perform their tasks simultaneously. The user, using the interface, has the opportunity to inform other participants of the experiment about the current state of affairs, identify critical situations, receive information about the object from other participants and display it on various visualization systems, monitor the progress of the experiment in real time, change various parameters of the model, observe how it affects the results; model the necessary modes of operation of the object, dangerous modes, external influences and the operation of the control system, start and stop a certain mode of refinement, etc. It also starts tools for automatic filling in the journal of protocol and processing of experiment results.

The proposed intellectual interface will improve the quality and efficiency of the user's work of the semi-natural modelling system, which

will generally reduce the time and cost of development, increase reliability.

PERFORMANCE METRICS OF IOT AND AR INTERACTION

Y. Yakovliev, O. Yelisieieva
Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine
yakyurlen@ukr.net, evo55555@ukr.net

The Internet of Things (IoT) and Augmented Reality (AR) are advanced technologies that significantly impact various industries today, including manufacturing, healthcare, education, and entertainment. The interaction between these technologies opens up new opportunities for enhancing process efficiency, improving user experience, and creating innovative products and services. The IoT essentially represents an interconnected network of devices and systems that collect and exchange various data. AR is designed to visualize this data conveniently at the moment it is needed, overlaying computer-generated objects onto the user's real environment. The relevance of the research lies in the need to develop methods for objectively assessing the effectiveness of IoT and AR integration, which will maximize their potential and identify areas for further improvement.

Assessing the interaction of these technologies requires the use of analytical models that help quantitatively evaluate their effectiveness and identify areas for improvement. The authors have attempted to develop an analytical model that includes key metrics necessary for evaluating the interaction of IoT and AR. The main metrics are divided into several groups: performance metrics, accuracy metrics, immersiveness metrics, security metrics, economic efficiency metrics, energy efficiency and system scalability metrics. Formulas and models have been developed for the quantitative assessment of the metrics of IoT and AR interaction. Each group of metrics corresponds to a numerical parameter value. The effectiveness of the interaction is considered as a functional dependence on the most significant parameters. To obtain the necessary parameter values, the expert assessment method was used. The proposed model was applied in the example of an augmented reality module for mobile applications developed by the authors.

The study of IoT and AR interaction using the proposed analytical model will provide objective data on their effectiveness, identify key problems, and suggest ways to solve them. The research results will be

useful for developers and researchers involved in the integration of these technologies in various fields, as well as for end-users who will be able to obtain higher quality and more effective solutions.

THE BIHAVIOUR OF MULTIDIMENSIONAL RENEWAL EQUATION

O.A. Yarova
Ivan Franko National University of Lviv, Ukraine
oksana.yarova@lnu.edu.ua

Consider semi-Markov process with a finite set of states and a continuous time $X(t), t > 0$. Denote the set of states $\{1,2, \dots, n\}$.

Let $\tau_1 = inf_{t>0}\{t: X(t) \neq X(0)\}$ - the moment of the first exit from the initial state. Then $\tau_2 = inf_{t>\tau_1}\{t: X(t) \neq X(\tau_1)\}$ - the moment of the second exit from the state $X(\tau_1)$.

So, $\tau_n = inf_{t>\tau_{n-1}}\{t: X(t) \neq X(\tau_{n-1})\}$ - the moment of the n exit from the state (τ_{n-1}).

Next, consider the sequence of process with independent increments $\xi_i(t), i = 1,2, \dots n$. Processes $X(t)$ and $\xi_i(t)$ are independent. Beside this, independent copies of the process with independent increments $\xi_i^{(n)}(t)$, $n = 1,2, \dots \infty, i = 1,2, \dots m$ are independent of each other and independent of process $X(t)$.

Then we construct a random evolution $\zeta(t)$ and build multidimensional renewal equation. After this, we research the behaviour of this process.

References

1. Nishchenko I.I. Transition phenomena for many-dimensiona renewal equation of spetial kind. // Theory of Stochastic Processes. – 2000. – Vol. 6(22), 1-2. – P. 107-115.
2. Koroliuk V.S. Stochastic systems in merging phase space / V.S. Koroliuk, N. Limnios. – Singapore: World Scientific Publishing Company, 2005. – 348 p.

MAKING CREDIT DECISIONS BASED ON BAYESIAN STRATEGIES

O. Zhukovska
National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute" , Ukraine
zhukovskaya71@gmail.com

There are two different approaches to making a decision on issuing or refusing a loan [14]: scoring systems and subjective expert opinion. To integrate scoring systems and personal decisions of experts, various approaches to collective decision making are used. An approach to making credit decisions based on Bayesian strategies is proposed.

Collective decision $D = m$, $m = \overline{1, M}$ optimal from the point of view of minimum average risk on the set

$$\mathbf{\Theta} = \{S_{m_1 \dots m_N} : (\delta_1 = m_1) \wedge \dots \wedge (\delta_N = m_N),\ m_1, \dots, m_N = \overline{1, M}\}$$

of possible combinations of private decisions of individual experts about the class of a potential borrower in the form of an indicator variable $\delta_i = m$ (when the i-th expert, $i = \overline{1, N}$ made a decision in favor of the class V_m, $m = \overline{1, M}$), if in an observed situation $S \in \mathbf{\Theta}$ a collective decision $D_S = \overline{1, M}$ $m = \overline{1, M}$ is made according to the scheme

$$D_S^{opt} = \arg \min_{D_S \in [1, M]} \sum_{k=1}^{M} L_{kD_S} P(V_k) \prod_{i=1}^{N} P(\delta_i = m \mid V_k),$$

L_{km} – losses from a collective decision $D = m$, $m = \overline{1, M}$ with the true class of the borrower V_k, $k = \overline{1, M}$. The specified classes have prior probabilities $P(V_m)$, $\sum_{m=1}^{k} P(V_m) = 1$. The scoring system in this model acts as one of the experts.

References

1. Crook J. Credit scoring: An overview – Working paper series No. 96/13, British Association, Festival of Science. University of Birmingham, The University of Edinburgh, 1996.
2. Zhukovska O. Decision-making model on potential borrower lending for in-dependent experts group. Proc. IEEE 3rd Intern. Conf. on System Analysis & Intelligent Computing (SAIC) (4–7 Oct. 2022, Kyiv, Ukraine). P. 118–121. http://doi.org/10.1109/SAIC57818.2022.9923015

Підписано до друку 16.06.2024. Формат 60х84/16.
Папір офсетний. Гарнітура Таймс. Друк офсетний.
Ум. друк. арк. 6,9. Наклад 120. Зам. № 211.

Надруковано в “Видавництво Людмила”.
Свідоцтво про внесення до Державного реєстру суб’єктів
видавничої справи серія ДК № 5303 від 02.03.2017.
“ Видавництво Людмила ”
03148, Київ, а/с 115.
Тел./факс: +38 050 469 7485, 068 340 8332
E-mail: lesya3000@ukr.net