Taras Shevchenko National University of Kyiv (Ukraine),
Azerbaijan State Pedagogical University (Republic of Azerbaijan),
Sheki branch Azerbaijan State Pedagogical University (Republic of Azerbaijan),
Lankaran State University (Republic of Azerbaijan)
International Institute for Applied Systems Analysis (Austria),
Glushkov Institute of Cybernetics of NAS of Ukraine,
Institute of Mathematics and Mechanics of NAS of Azerbaijan,
Higher School Academy of Sciences of Ukraine,
Noosphere Ventures Corporation (Ukraine),
European Education Center (Georgia)

XXXVII International Conference

PROBLEMS OF DECISION MAKING UNDER UNCERTAINTIES (PDMU-2022)

November 23 – 25, 2022

ABSTRACTS

Sheki-Lankaran,
Republic of Azerbaijan

Kyiv
2022

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 № 4 від 16.11.2022 р.)

ISBN 978-617-555-065-6

CONTENT[1]

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

ECONOMETRIC ANALYSIS OF SUSTAINABLE DEVELOPMENT INDICATORS

Aytakin Telman Afandiyeva
Baku State University, Azerbaijan
aytek@mail.ru

The main purpose of the study is to analyze the relationship between Gross Domestic Product (GDP) and Science Costs (SC), one of the indicators affecting the sustainability of socio-economic development in the Republic of Azerbaijan. Using the methods of economic-mathematical modeling, the study examined whether there is a relationship between GDP and SC in the Republic of Azerbaijan and analyzed the statistical data related to the variables econometrically.

The models based on the statistical data of the State Statistics Committee of Azerbaijan for 1990-2021 were found on a personal computer using the Eviews'11 application program using the smallest squares method and evaluated by correlation-regression analysis. As a result of the study, descriptive statistics on the variables used were calculated and *skewness*, *kurtosis* and *Jarque-Bera* test statistics were analyzed. *ADF Stationary* (Single Root) Tests for *Level* and *First* Differences of Variables were performed. After analyzing the long-term relationship between GDP and Science Costs, the ADF unit root test was applied to the errors calculated based on the estimated results of the model. An Error Correction Model has been established to determine how long it takes for deviations from the long-run equilibrium value between variables to be corrected.

After graphs, descriptive statistics, and correlation analysis of the variables used in the analysis, tests for the econometric model were performed.

References

1. Statistical indicators of Azerbaijan: Baku, 2021. – 308 p.
2. Dougherty K. Introduction to Econometrics. Per. with eng. – M.: INFRA-M, 2009. – 465 p.
3. Matyushok V.M. Fundamentals of econometric modeling using EVIEWS. Textbook, 3rd Edition. – Moscow, 2015. – 228 p.

CONTROL OF A DYNAMIC OBJECT WITH INEXACTLY GIVEN PARAMETERS AND INITIAL CONDITIONS

K.R. Aida-zade[1,2], S.A. Aliyev[1,2]
[1]Institute of Control Systems of NAS of Azerbaijan
[2]Institute of Mathematics and Mechanics of NAS of Azerbaijan
kamil_aydazade@rambler.ru, soltanaliyev@yahoo.com

The problem of optimal control of the following system is considered:

$$\dot{x}(t) = f(x(t), u(t), p),\ t \in [t_0, t_f], \tag{1}$$

$$x(t_0) = x^0 \in X^0 \subset R^n. \tag{2}$$

Here $x(.) \in R^n$ – phase trajectory; $u(t) \in U \subset R^r$ – control; U – convex, closed range of valid values of control; $p \in P \subset R^m$ – object parameters and x^0 – the initial state are not exactly specified. The corresponding density functions are given:

$$0 \le \rho_P(p) \le 1,\ \int_P \rho_P(p)\,dp = 1,$$

$$0 \le \rho_{X^0}(x^0) \le 1,\ \int_{X^0} \rho_{X^0}(x^0)\,dx^0 = 1.$$

It is required to minimize the given objective functional

$$J(u) = \int_{X^0}\int_P f^0\left(x(t), u(t), p\right)\rho_{X^0}(x^0)\rho_P(p)\,dp\,dx^0\,dt. \tag{3}$$

The problem (1)-(3) is a problem of controlling a bundle of trajectories. For this, the necessary optimality conditions are obtained, and a numerical scheme for the solution using first-order optimization methods is constructed. The results of computer experiments are presented.

References

1. Aida-zade K.R., Bagirov A.H., Hasimov V.A. Feedback control of the power of moving sources when heating the bar // Cybernetics and Systems Analysis, Springer. – 2021. – 57(4). – P. 592-604. DOI:10.1007/s10559-021-00384-4

2. Aida-zade K.R., Abdullayev V.M. Numerical solution of the problem of determining the number and locations of state observation points in feedback control of a heating process // Computational Mathematics and Mathematical Physics. – 2018. – Vol.58(1). – P.78-89. DOI: 10.1134/S0965542518010025.

FINDING THE SOLUTION OF A MIXED PROBLEM FOR A QUADRATIC SPECIAL DIFFERENTIAL EQUATION

Saleh Ahmadov*, Rashid Gasimov**
Lankaran State University, Azerbaijan
salehakhmedov1973@gmail.com*, resid5757@mail.ru**

Consider the following problem:

$$\frac{\partial u\ x,t}{\partial t}=i\frac{\partial^4 u\ x,t}{\partial x^4}+q\cdot\frac{\partial^2 u\ x,t}{\partial x^2},\ \ 0<x<1,\ t>0, \tag{1}$$

$$u\ x,0\ =\phi\ x\ , \tag{2}$$

$$L_p\ u\ \equiv\sum_{k=1}^{3}\left(\alpha_{pk}\frac{\partial^{k-1}u\ 0,t}{\partial^{k-1}x}+\beta_{pk}\frac{\partial^{k-1}u\ 1,t}{\partial^{k-1}x}\right)=0,\ \ p=\overline{1,4}, \tag{3}$$

where q, α_{pk},β_{pk} ($p=\overline{1,4}$, $k=\overline{1,3}$) are complex numbers, $\varphi(x)$ are complex valued functions.

After application integral transformation $y(x,\lambda)=\int_0^\infty u(x,t)e^{-\lambda^4 t}dt$ to the problem (1)-(3), we'll get following spectral problem:

$$iy^{IV}+qy''-\lambda^4 y=-\phi\ x\ ,\ \ 0<x<1 \tag{4}$$

$$L_p\ \ y\ \equiv\sum_{k=1}^{3}\ \alpha_{pk}y^{(k-1)}(0,\lambda)+\beta_{pk}y^{(k-1)}(1,\lambda)\ =0,\ \ p=\overline{1,4}. \tag{5}$$

Now to find asymptotic of eigenvalues of spectral problem (4), (5) consider the following theorem:

Theorem 1. Suppose, that q,α_{pk},β_{pk} ($p=\overline{1,4}$; $k=\overline{1,3}$) are complex numbers, which has first order continuous derivatives on $[0;1]$. Then the zeros of the characteristic determinant $\Delta\ \lambda$ are countable set, single limit points of which is $\lambda=\infty$ and the following formulas for the asymptotic zeros are true:

$$\lambda_n^4=\ 4n^4+8n^3+6n^2\ \ \pi^4 i-\pi^2 n^2\left(\int_0^1 q\ \ \tau\ \ d\tau+4i\frac{B_0\pm C_0}{A_0}\right)+O\ \ n \tag{6}$$

$n\to\pm\infty$

As it is known, that at $\mathrm{Re}\,q>0$, equation (1) is parabolic in the sense of Shilov [4]. A following theorem allows us to find solution of the mixed

problem (1)-(3) not only in case of parabolic in the sense of Shilov, but also wider classes:

Theorem 2. Suppose, that functions $g(x)$ and $\phi(x)$ are satisfies to a following conditions $\phi\ 0 = \phi\ 1 = \phi'\ 0 = \phi'\ 1 = 0, \quad \mathrm{Re}\, q > 0.$ If $A_0 \neq 0$, coefficients of the boundary conditions are complex numbers and

$$\mathrm{Im}\frac{B_0 \pm C_0}{A_0} = 0,$$

$$A_0 = 2L(\alpha_2\alpha_3\beta_2\beta_3),$$

$$B_0 = 2\ L(\alpha_2\alpha_3\beta_1\beta_3) - L(\alpha_1\alpha_3\beta_2\beta_3)\ ,$$

$$C_0 = 2\big(L(\alpha_1\alpha_2\alpha_3\beta_3) + L(\alpha_3\beta_1\beta_2\beta_3)\big)$$

then mixed problem (1)-(3) has following solution

$$u\ x,t\ = -i\sum_{k=1}^{4}\sum_{n=1}^{\infty} res_{\lambda=\lambda_{km}}\ \lambda^3 e^{\lambda^4 t}\int_0^1 G\ x,\xi,\lambda\ \phi\ \xi\ d\xi, \qquad (7)$$

here $G\ x,\xi,\lambda$ is a Green function of the corresponding spectral problem, $\lambda_{kn}\quad k = \overline{1,4}; n = 1,2,3,...$ are all zeroes of the characteristic determinant $\Delta(\lambda)$.

References

1. Naimark M.A. Linear differential operators. – Moscow, Nauka, 1969. – 528 p.
2. Rasulov M.L. Method of contour integration. - M.: Science, 1964. – 462 p.
3. Mamedov Yusif A., Ahmadov Saleh Z. On solution of a mixed problemfor an equation of the fourth order with discontinuous coefficient.// Transaction of National Academy of sciences of Azerbaijan, Baku. – 2006. – Vol. XXVI, №4, – P. 137-144.
4. Eidelman S.D. Parabolic systems. – Moscow, Nauka, 1964. – 443 p.

ON AN INVERSE PROBLEM FOR A PARABOLIC EQUATION IN A DOMAIN WITH MOVING BOUNDARIES

[1]**Adalat Ya. Akhundov,** [2]**Arasta Sh. Habibova**

[1]Institute of Mathematics and Mechanics of NAS of Azerbaijan, Azerbaijan

[2]Lankaran State University, Azerbaijan

adalatakhund@gmail.com

This paper considers the inverse problem of determining the unknown coefficient on the right-hand side of a parabolic equation in a domain with moving boundaries. An additional condition for finding the unknown coefficient, which depends on the variable time, is given in integral form. A theorem on uniqueness and "conditional" stability of the solution is proved.

Let $\gamma_1(t), \gamma_2(t) t \in [0,T], 0 < T = const$ be the given functions, (x,t) be an arbitrary point in the bounded domain $D = (\gamma_1(t), \gamma_2(t)) \times (0,T]$, $[a,b]$ be the projection of the domain D into the axis OX.

We consider the following inverse problem on determining a pair of functions $\{f(t), u(x,t)\}$:

$$u_t - u_{xx} = f(t)g(x) \ (x,t) \in D, \tag{1}$$

$$u(x,0) = \varphi(x) \ x \in [\gamma_1(0), \gamma_2(0)], \tag{2}$$

$$u(\gamma_1(t),t) = \psi_1(t), \ u(\gamma_2(t),t) = \psi_2(t), t \in [0,T], \tag{3}$$

$$\int_{\gamma_1(t)}^{\gamma_2(t)} u(x,t)dx = h(t), \ t \in [0,T], \tag{4}$$

where $g(x), \varphi(x), \psi_1(t), \psi_2(t), h(t)$ are the given functions, $u_t = \dfrac{\partial u}{\partial t}$, $u_x = \dfrac{\partial u}{\partial x}$, $u_{xx} = \dfrac{\partial^2 u}{\partial x^2}$.

We make the following assumptions for the data of problem (1)-(4):

1^0. $g(x) \in C^{\alpha}[a,b], \int_{\gamma_1(t)}^{\gamma_2(t)} |g(x)| dx \geq c_1 > 0;$

2^0. $\varphi(x) \in C^{2+\alpha}[\gamma_1(0), \gamma_2(0)];$

3^0. $\psi_1(t), \psi_2(t) \in C^{1+\alpha}[0,T], \varphi(\gamma_1(0)) = \psi_1(0), \varphi(\gamma_2(0)) = \psi_2(0);$

4^0. $h(t) \in C^{1+\alpha}[0,T];$

$5^0.\gamma_1(t),\gamma_2(t)\in C^{1+\alpha}[0,T], 0<c_2\le\gamma_2(t)-\gamma_1(t)\le c_3<+\infty, t\in[0,T]$

where c_1, c_2 and c_3 are positive constants, $\alpha\in(0,1)$.

Definition 1. The pair of functions $\{f(t),u(x,t)\}$ is called the solution of problem (1) - (4) if

1) $f(t)\in C^{\alpha}[0,T]$;

2) $u(x,t)\in C^{2+\alpha,1+\alpha/2}(D)\bigcap C(\bar{D})$;

3) The conditions (1)-(4) hold for these functions.

Define the following set:

$$K_{\alpha}=\{(f,u)\,|\,f(t)\in C^{\alpha}[0,T],|f(t)|\le c_4, t\in[0,T],$$
$$u(x,t)\in C^{2+\alpha,1+\alpha/2}(\bar{D}),|u|,|u_x|,|u_{xx}|\le c_5,(x,t)\in\bar{D}\},$$

where c_4, c_5 are some positive constants. Let us assume that the two input sets $\{g(\cdot),\varphi(\cdot),\psi_1(\cdot),\psi_2(\cdot),h(\cdot)\}$ and $\{\bar{g}(\cdot),\bar{\varphi}(\cdot),\bar{\psi}_1(\cdot),\bar{\psi}_2(\cdot),\bar{h}(\cdot)\}$ are given for Problem A. For brevity of the further exposition, Problem A with the second input set we will call Problem $\bar{A}$. Let $\{f(t),u(x,t)\}$ and $\{\bar{f}(t),\bar{u}(x,t)\}$ be solutions of problems A and $\bar{A}$, respectively.

Theorem 1. Let the following conditions hold

1) The functions $\{g(\cdot),\varphi(\cdot),\psi_1(\cdot),\psi_2(\cdot),h(\cdot)\}$ and $\{\bar{g}(\cdot),\bar{\varphi}(\cdot),\bar{\psi}_1(\cdot),\bar{\psi}_2(\cdot),\bar{h}(\cdot)\}$ satisfy conditions 1^0-4^0, respectively;

2) The functions $\gamma_1(t),\gamma_2(t)$ satisfy condition 5^0;

3) Solutions of problems A and $\bar{A}$ exist in the sense of definition 1 and they belong to the set K_{α}.

Then there exists a $T^*\left(0<T^*\le T\right)$, such that for $(x,t)\in[\gamma_1(t),\gamma_2(t)]\times[0,T^*]$ the solution of problem (1)-(4) is unique, and the stability estimate

$$\|u-\bar{u}\|_D^{(0)}+\|f-\bar{f}\|_T^{(0)}\le c_6\Big[\|g-\bar{g}\|_{[a,b]}^{(0)}+$$
$$+\|\varphi-\bar{\varphi}\|_{[a,b]}^{(2)}+\|\psi_1-\bar{\psi}_1\|_T^{(0)}+\|\psi_2-\bar{\psi}_2\|_T^{(0)}+\|h-\bar{h}\|_T^{(1)}\Big],$$

is valid, where $c_6>0$ depends on the data of problems A and $\bar{A}$ in the set K_{α}.

THE IMPACT OF THE GEORGIAN LANGUAGE IN THE PROCESS OF LEARNING GERMAN AS A FOREIGN LANGUAGE

Neli Akhvlediani
Batumi Shota Rustaveli State University, Georgia

The report presents an analysis of the common mistakes made by the influence of the Georgian language in learning German as a foreign language. The research aims to review the Batumi Shota Rustaveli State University students written texts, classifying and identifying errors, conduct contrast analysis.

A research target is a group of 24 second-year students of English philology. As a result of the analysis of errors made in written texts, interlingual and intralingual interferences were determined. Interlingual intervention can be defined as "the process and result of the influence of linguistic features and rules from the native language to the foreign language." (Dieling/Hirschfeld 2001, 181) Intralingual interference represents the interaction of specific linguistic phenomena within the same language (Kleppin, 1998), according to Corder (1973, 257).

After analyzing the written texts by the 24 students studying German as a foreign language at Batumi Shota Rustaveli State University, the observation has shown that students transfer errors not only from their native but also from the influence of their first or second foreign languages into the German language. This means that they frequently unknowingly rely on previous language experience (often native, but not only), which is precisely the cause of mistakes in learning German. The present article deals with all the above issues.

References

1. Corder, S. Pit. 1973. Introducing Applied Linguistics. London: Penguin Education.
2. Dieling, Helga, Hirschfeld, Ursula. Phonetik lehren und lernen:Fernstudieneinheit, 2001, 2.Aufl.
3. Kleppin, Karin. 1998. Fehler und Fehlerkorrektur. München: Langenscheidt Verlag.

ONLINE DICTIONARIES AND TRANSLATION

Zeinab Akhvlediani
Batumi Shota Rustaveli State University, Georgia

The modern era, as many scientists note, is distinguished by lexicographic innovations and new stages of development. As you know, progress in lexicography is a necessary condition for successful translation.

Lexicographic success is determined by the constant updating of the dictionary by competent persons and taking into account the requirements of users.

Despite modern technological progress and the development and correction of technological theories using online dictionaries by groups of scientists, a number of shortcomings remain unresolved, which, in turn, prevents a full-fledged computer translation.

Before transferring lexical material to an electronic system, the most important factor is grammatical and semantic data processing, since independent perception of flexible forms of a word and the corresponding analysis are beyond the capabilities of a computer. For example: to create an electronic dictionary, along with the translation of a word, it is necessary to take into account its grammatical and semantic changes: the origin of the word, conjugations, vowel dropouts, synonymous and antonymic description of the word, contextual definitions, etc. The meaning of a single word in many cases does not match its contextual definition in a sentence, so the range of use of the word should be described as widely as possible, because the computer will be able to adequately respond to an existing request only on the basis of fixed material.

The solution of this general computer-linguistic problem leads to the development of computer linguistics, which, based on the combined experience and knowledge of programmers and linguists, will allow describing the lexical fund of a language in an electronic system and providing a full-fledged and instantaneous translation of a single word or text.

The present article deals with all the above issues.

SEMANTIC AND SYNTAXIC ASPECTS OF MODEL BUILDING

T. T. Aleskerzadeh
Lankaran State University, Azerbaijan
aleskerzade.tale@gmail.com

An important aspect of modeling is to replace of a real system by its analogue – a model. In this case, in the semantics of the model, the parameters corresponding to the real object must be consistent in the model in the form of input and output values and states. And also in the syntax of the model of the relationship between the agreed values in the form of formulas.

The model must have the obligatory ability to expand, i.e., a real opportunity to introduce new knowledge into the built model. The structure of the model is represented by a graph, the vertices of which are occupied by the components of the reference information, and the edges are occupied by the main relations. The representation of the model includes the choice of the environment and its states, with the help of which both the reference information and the main relations are encoded. Therefore, in the case of constructing models, we are talking about bringing to the fore the syntactic side of this construction. Let us consider the features of the semantic and syntactic aspects of building models:

- The semantics of the model is its content, its meaning, everything that ensures the correspondence between the parameters of the model and the original.
- The semantics of the model must be consistent with the user.
- The syntax of a model is a form for semantics, that is, a set of formal auxiliary means of a model for representing its basic information, basic relations and hierarchical structure.
- To represent any model, basic syntactic elements and their connections are necessary.

References

1. Bashmakov A.I., Bashmakov I.A. Intelligent information technologies: study guide. – Moscow: Bauman MSTU, 2005. – 304 p.
2. Levin B.R., Schwarze V. Probabilistic models and methods in communication and control systems. – Moscow: Radio and communication, 1985. – 312 p.
3. Sterman J.D. System Thinking and Modeling for a Complex World. – Moscow: Graw Hill, 2000. – 982 p.

SOLUTION OF THE CAUCHY PROBLEM FOR ν ORDER ORDINARY DIFFERENTIAL EQUATION WITH A CONTINUOUSLY VARYING ORDER OF DERIVATIVE

[1]N.A. Aliyev, [2] R.H. Ahmadov

[1,2]Baku Satae University, Baku, Azerbaijan

[1]**nihan.aliev@gmail.com, [2]ahmadov_ramiz@hotmail.com**

In the present paper, we consider the problem of determining the solution of $y(x)$ that satisfies the initial condition

$$D^{\alpha} y\ x\ \Big|_{x=x_0} = \phi\ \alpha\ ,\alpha \in [0,\nu) \tag{1}$$

of the differential equation of ν order $(\nu > 0, \nu \in R)$.

$$\int_0^{\nu} a\ \alpha\ D^{\alpha} y\ x\ d\alpha = 0, x \geq x_0 > 0. \tag{2}$$

The solution of problem (1)-(2) is founded based on the known Voltaire function [1] as follows:

$$y\ x\ = y\ x,\lambda\ = \int_{-1}^{\infty} \frac{x^{\beta}\lambda^{\beta}}{\beta!} d\beta = \int_{-1}^{\infty} \frac{x\lambda\ ^{\beta}}{\beta!} d\beta. \tag{3}$$

Considering the form (3) of the solution $y(x)$ is shown that

$$D^{\alpha} y\ x\ = \lambda^{\alpha} \int_{-1}^{\infty} \frac{(\lambda x)^{\gamma}}{\gamma!} d\gamma = \lambda^{\alpha} y\ x\ ,\ \lambda \geq 0 \tag{4}$$

and from here we get $\int_0^{\nu} a\ \alpha\ \lambda^{\alpha} d\alpha = 0.$ A regular distribution of the segment o,ν with step $h = \frac{\nu}{n}\ n \geq 2, n \in N$ is defined and the function $a(\alpha)$ is assumed as a step function $a(\alpha) = a_j\ ,\alpha \in (j-1)h, jh\ ,\ a_j = const$. Then according to the equation (4)

$$\sum\nolimits_{j=1}^{n} a_j \int_{(j-1)h}^{jh} \lambda^{\alpha} y(x) d\alpha$$

or

$$\sum_{j=1}^{n} a_j \int_{(j-1)h}^{jh} \lambda^{\alpha} d\alpha = 0$$

and denoting $\rho = \lambda^h$, we get

$$a_n \rho^n + (a_n - a_{n-1})\rho^{n-1} + \cdots + (a_2 - a_1)\rho + a_1 = 0.$$

Assuming that the last equation has exactly n number of different solutions and $\lambda_k = \sqrt[h]{\rho_k} = \rho_k^{1/h}$, then the solution $y(x)$ can be defined as

$$y\ x\ = \sum_{k=1}^{n} C_k \int_{-1}^{\infty} \frac{x^{\beta} \rho^{\beta/h}}{\beta!} d\beta.$$

The coefficients C_k are determined by the initial condition (1).

References

1. Volterra, V. (1930) *Theory of Functionals and of Integral and Integro-Differential Equations*, Blackie & Son Limited, 226 p.
2. Aliev, N.A., Ahmadov, R.G. (2020) On one boundary value problem for the first order ordinary differential equation with a continuously varying order of derivative, *Proc. of the 7th Int. Conf. on Control And Optimization with Industrial Applications*, Vol.1, p. 98-100.

ONE BOUNDARY PROBLEM FOR EQUATION KOSHI-RIMAN IN UNIT SQUARE

Nihan Aliyev[1], Laura Fatullayeva[2], Rena Orujova[3]

[1,2]Baku State University, Azerbaijan

[3]Azerbaijan State Agrarian University, Azerbaijan

[1]cefer_nihan38@mail.ru, [2]laura_fat@rambler.ru, [3]laura_azpar@rambler.ru

Consider the following problem:

$$\frac{\partial u(x)}{\partial x_2} + i\frac{\partial u(x)}{\partial x_1} = 0,\ x_k \in (0,1),\ k = 1,2, \tag{1}$$

$$\begin{cases} u(x_1,1) + au(x_1,0) = \phi(x_1), & x_1 \in [0,1], \\ u(1,x_2) + bu(0,x_2) = \psi(x_2), & x_2 \in [0,1], \end{cases} \tag{2}$$

where $i=\sqrt{-1}$, a,b - are real constants and $\phi(x_1), \psi(x_2)$ - are continuous functions of their arguments. Fundamental in the direction of x_2 solution of equation (1) has the form:

$$U(x-\xi)=e(x_2-\xi_2)\delta(x_1-\xi_1-i(x_2-\xi_2)). \tag{3}$$

From formulas (3) and (1) we obtain the main relation:

$$\int_0^1 u(x_1,1)e(1-\xi_2)\delta(x_1-\xi_1-i(1-\xi_2))dx_1 -$$

$$-\int_0^1 u(x_1,0)e(-\xi_2)\delta(x_1-\xi_1+i\xi_2)dx_1 +$$

$$+i\int_0^1 u(1,x_2)e(x_2-\xi_2)\delta(1-\xi_1-i(x_2-\xi_2))dx_2 -$$

$$-i\int_0^1 u(0,x_2)e(x_2-\xi_2)\delta(-\xi_1-i(x_2-\xi_2))dx_2 =$$

$$=\begin{cases} u(\xi), & \xi_k\in(0,1),\ k=1,2; \\ \dfrac{1}{2}u(\xi), & \xi_1\in[0,1],\ \xi_2=0 \ \textit{или}\ \xi_2\in[0,1],\ \xi_1=0. \end{cases} \tag{4}$$

So $u(t,1)$ and $u(0,t)$ are determined from the boundary conditions (2). If we take into account the boundary conditions, then the solution of the problem (1)-(2) is obtained from the main relation (4).

AGE DEPENDENT BRANCHING PROCESSES

[1,2]S.A. Aliyev, [1]I.A. Ibadova
[1]Institute of Mathematics and Mechanics of NAS of Azerbaijan
[2]Institute of Control Systems of NAS of Azerbaijan
soltanaliyev@yahoo.com

Let us consider a branching process model, where each particle has a

random life time, and by its end generates descendants. This process should be compared to branching processes whose life time of a particle is fixed or exponentially distributed.

Assume that a separate particle has a life time of random duration T with density $f(t)$, i.e. the probability that the life time of a particle lies in the interval $(t, t+dt)$ equals $f(t)dt$. Further assume that by the end of life time a particle generates two new particles of the same type whose life time will be independent random variables with the some density $f(t)$. By the end of its lifetime each particle again generates two new particles of the same type, and this process continues indefinitely.

Let now ξ_n, $n = 0,1,2,...$ be a branching random process with discrete time, $p_0, p_1, ..., p_n, ...$ be distribution of the number of descendants of a particle. Each particle lives random time τ, and at the end of its life gives $0, 2, 3, ...$ descendants.

To each existing particle we associate "age" and fix a non-negative integer $\vartheta \geq 0$, $\vartheta = 0,1,2,...$ and consider the sequence η_n^{ϑ} the number of particles existing at the time n whose age equals ϑ.

In this case, the object of the study of our paper will be two-dimensional process $(\xi_n, \eta_n^{\vartheta})$ with the generating function $F_n(s,z) = M\, s^{\xi_n} z^{\eta_n^{\vartheta}}$.

The goal of this paper, in the special case, when lifetime of the particle τ has geometrical distribution with the parameter q, i.e. $P\{\tau = k\} = q^{k-1}(1-q)$, $k = 1,2,...$ is to study probability characteristics and under certain conditions on the generating function $F_n(s,z)$ to prove limit theorems for the processes $(\xi_n, \eta_n^{\vartheta})$.

This work was supported by the Science Development foundation under the President of the Azerbaijan (Argument Number N EIF-ETL-2020-2(36)-16/05/1-M-05).

NUMERICAL SOLUTION OF INITIAL-BOUNDARY VALUE PROBLEM FOR ONE-DIMENSIONAL GAS DYNAMICS IN THE CLASS OF DISCONTINUOUS FUNCTIONS

E. Aliyev[1], M. Rasulov[2], M. Xalilov[1]
[1]Baku State Universite, Azerbaıjan
[2]Ministry of Science and Education of The Republic of Azerbaijan
Institute of Oil and Gas**,** Azerbaijan
emin.aliev3008@gmail.com; **khalilov_mubariz@mail.ru**;
mresulov@ gmail.com

In this study we develop numerical method for solving the initial-boundary value problem for the first-order nonlinear partial differential system of equations described the one dimensional motion of izentropic gas as follows

$$\begin{cases} u_t + uu_x = 0, \\ \rho_t + (\rho u)_x = 0, \end{cases}$$

$$u(x,0) = u_0(x), \rho(x,0) = \rho_0(x),$$

$$u(0,t) = u_1(t), \rho(0,t) = \rho_1(t).$$

Here the $u_0(x), \rho_0(x), u_1(t)$ and $\rho_1(t)$ are given functions that even though may be piecewise continuous.

It is known that the solutions of this type problem has the points of discontinuities even if the initial function is sufficiently smooth. Since a discontinuous function does not satisfy a differential equation in a classical sense, it is necessary to introduce the concept of a weak solution. In order to find the weak solution, the special auxiliary problem is introduced, since it has some advantages over the main problem and permits to obtain the numerical solution in a class of discontinuous functions. Using the advantages of the auxiliary problem some numerical algorithms are suggested which accurately exhibit all genual nature of the physical prosseses.

References

1. Abasov M.T., Rasulov M.A., Ibrahimov T.M., Ragimova T.A. (1991) On a method of Solving the Cauchy Problem for a First Order Nonlinear Equation of Hyperbolic Type with a Smooth Initial Condit., *Sov.Math.Dok.*, 43(1), 150-153.
2. LeVeque R.J. (2002) *Finite Volume Methods for Hyperbolic Problems*, Cambridge University Press, 558 p.
3. Rasulov M.A., Ragimova T.A. (1992) A Numerical Method of the Solution of Nonlinear Equation of a Hyperbolic Type of the First Order, *Diff. Equat.,* 28(7), 2056-2063.

ON THE CONVERGENCE ANALYSIS OF KURCHATOV-TYPE METHODS

I.K. Argyros[1], S.M. Shakhno[2], H.P. Yarmola[2]
[1]Cameron University, USA
[2]Ivan Franko National University of Lviv, Ukraine
iargyros@cameron.edu, stepan.shakhno@lnu.edu.ua, halyna.yarmola@ lnu.edu.ua

Let X and Y be Banach spaces and Ω be a convex and nonempty subset of X. Let us consider a nonlinear equation

$$F(x)=0, \tag{1}$$

where $F:\Omega\subseteq X\to Y$ is a Fréchet-differentiable operator. For numerical solving of (1) the two-step methods

$$\begin{aligned} y_n &= x_n - A_n^{-1}F(x_n),\\ x_{n+1} &= y_n - A_n^{-1}F(y_n),\ n\geq 0 \end{aligned} \tag{2}$$

and [1]

$$\begin{aligned} y_n &= x_n - A_n^{-1}F(x_n),\\ x_{n+1} &= y_n - B_n^{-1}F(y_n),\ n\geq 0, \end{aligned} \tag{3}$$

where $A_n = F(2x_n - x_{n-1}, x_{n-1})$ and $B_n = F(2y_n - x_n, x_n)$, are applied. These iterative processes are two-step modification of the Kurchatov method [2].

We study a local and a semi-local convergence of the methods (2) and (3) under classical and generalized Lipschitz conditions for the divided differences of the first order. The conditions and speed of convergence of these methods are determined. To develop a convergence analysis we use the approach of restricted convergence regions. The semi-local convergence is based on majorizing scalar sequences. Moreover, the domain of uniqueness of the solution is found. The results of numerical experiments validate the theoretical results.

References

1. Argyros I.K., Shakhno S.M., Yarmola H.P. On the convergence of Kurchatov-type methods using recurrent functions for solving equations // Matematychni Studii. – 2022. – Vol. 58, No.1. – P. 103-112.
2. Shakhno S.M. On a Kurchatov's method of linear interpolation for solving nonlinear equations // PAMM: Proceedings in Applied Mathematics and Mechanics. – 2004 – Vol. 4, No.1. – P. 650-651.

ON THE MORAL FACTORS OF POLITICAL RISK IN DECISION-MAKING PROCESS

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

The present scientific report outlines the issue of the possibility of formation of a worldview system through practical ethical requirements that regulates the reactionary politics of intellectual reality to probabilistic hazards. The report demonstratively shows that the ethical standards of universal prohibitions, the moral responsibility of human nature and the ethics of virtue make a conflict of social and political interests through insurmountable cognitive and discursive difficulties. The report tells that the fundamental ethical concepts of utilitarian thought of historical reminiscences integrates the possibility circumstances into the logical model of making morally important and useful decisions-making much easier, but in the valuating pragmatic context needs a main transformation in social terms of ideological metric and social-political structure.

The purpose of the report is trying to substantiate, base and ground that in order for the ethical of paroemiac responsibility and political freedom to be able to fulfill its social tasks, it is necessary to reach some worldview ideas: to create an universal model of moral consciousness; overcome mental and sociocultural biases regarding the assessment of the convincingness of events and determine the relevant logical reaction of society not only to a certain risk of hazard, but also to uncertainty regarding their intellectual decision-making for ethical operative proposals. These traditional paradigms are rational decision-making and practical decision-making such as "a statement of the purposes and maintenance with their policy, strategy, procedures and rules promotes the decision of this theoretical problem" [1] and "a perspective for distinguishing the function created in any medium, including with technologies" [2] and "the Recent centuries again brought human attention to the irrational sensory perception in discourses" [3]. The purpose of such mental experiments is to present new theoretical-worldview and paroemiac innovation directions for improving the social-cultural process used in the sphere of political risks.

The report discusses that the modernization of the social information technologies sphere is a key problem of state and educational policy

pursued in recent years. The most active intellectual members of political society strive to contribute voluntarily to the solution of the moral dilemmas and risk problems facing him. A strengthening of ethical innovative approaches and the development of managing techniques depend on the shaping of the values and judgments of the modernized and leading-edge society [4]. 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.

The report tells that a political risk manager must have a combination of analytical skills, practical experience, theoretical knowledge and moral personal qualities - curiosity and an inquiring mind like the English artistic literary character Mister Sherlock Holmes. Risks by logical system of Deductive risks of a genius private detective are known as innovation findings, outcomes and results of effective traditional scientific logic. It is nameworthy that the moral events of historical dilemmas usual fell into the sphere of public and political interests of the creativity character of Sir Arthur Conan Doyle - when he analyzes about the essence of the history of the evolution of the paroemiac views on the question of the moral existence of the cognitive mental risks in the process of the individual and personal logical decision-making. The pragmatic sphere of political risk includes some moral strategy and organizing tactics. The innovation approaches of strategy refer to the direction and way of using methods to achieve the goal. This classical effective empirical and approved method corresponds to a certain set of theoretical cognitive rules and restrictions for making an ethical worldview decision [5]. For them, Henry Alfred Kissinger - an American diplomat and international relations expert in his research-book "World Order" tells us: “an American Professor of Canon History John Scherer spoke at a Church Leadership Conference: "The churches will have to make a painful decision to be faithful to the secular kingdom or the kingdom of God" The professor found "many blatant violations of the First Amendment" in the past, that is, when the US government used the church as its tool in foreign affairs” [4]. We can note here that “a statement of the purposes and maintenance with their policy, strategy, procedures and rules promotes the decision-making of this moral problem” [4]

The report concludes that the innovation strategy of worldview techniques allows you to concentrate efforts on ethical decision-making options that do not contradict the adopted strategy, discarding all other

options. After achieving the set goal, strategy as a direction and means of achieving it ceases to exist. New goals pose the challenge of developing a new strategy. In social organizations, the formation of basic values goes a long way of transformation, as a result of which they, as a rule, become their needs or obligations to society. In this sense, the basic moral values are pragmatic, rational, and their choice is determined by the specifics of each social-political institution. And, at last, the author comes to the deciding and can make the following general moral output:

Nobody in the real world of social and public relations - from the highest officials, the largest scientists and famous creators and artists - is immune from the risks of political investigation...!

References

1. Bagrationi Irma, The Impact of Worldview Theory on the Decision Making Process in Business Education, Proceedings International Scientific Conference: PDMU-2021-XXXVI – "Problems of Decision Making Under Uncertainties", Kyiv: "Видавництво Людмила", 2021. pp. 14-16. (In English)

2. Bagrationi Irma, The Impact of Psychology on The Decision-Making Process In The Aesthetic Creativity, Proceedings International Scientific Conference: PDMU-2020 - XXXV - "Problems of Decision Making Under Uncertainties", Kyiv: "Видавництво Людмила", 2020. pp. 17-20. (In English)

3. Didmanidze Ibraim & Bagrationi Irma, On Educational Technologies for the Aesthetic Synesthesia Research, Journal "Cross-Cultural Studies: Education and Science (CCS&ES)", Volume 5, Issue II, ISSN: 2470-1262, Publisher: Beyer Thomas Robert, Vermont: "Middlebury College", USA, 2020. pp. 67-78. (In English)

4. Reproduced from the Publication: Nikolai Nikolaevich Yakovlev, CIA against the USSR, Moscow, Publishing Group "Pravda", 1983. – pp. 19-20. (In Russian)

5. Bayes Thomas, Essays in Bayesian Decision Theory, From the Book: An Essay towards Solving a Problem in the Doctrine of Chances, Series: "Essays on Moral Development", Publisher: "Royal Society of London", Volume Three, London, Re-Printed in "Pearson & Kendall and In-Press", 2003. – pp. 420. (In English)

THREE-STEP METHODS FOR FUNCTION MINIMIZATION WITH OVER QUADRATIC CONVERGENCE

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

$$f(x) \to min, x \in R^n . \tag{1}$$

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). Using well-known algorithms we build new one which uses information about function and its derivatives on every step more effectively. The new algorithm achieves a solution with fewer calculations than basis and has next view

$$\begin{aligned} u_k &= \Phi(x_k); \\ v_k &= x_k - f'(x_k, u_k)^{-1} f'(x_k); \\ x_{k+1} &= \arg\min_{\gamma} f\left(u_k + \gamma(v_k - u_k)\right); \end{aligned} \tag{2}$$

where $\Phi(x)$ - satisfied condition $\Phi(x) - x_* \le K x_k - x_*^{\tau}$. x_* - solution of the problem (1), $f'(x, y)$ - divided differences of vector-function $f(x)$, $\tau \in [1,2]$. If the corresponding conditions, according to (2), are met, a divergent sequence $\{f(x_k)\}$ will be obtained. The next evaluation takes place

$$f(x_k) - f(x_*) \le K \prod_{i=1}^{k} \gamma_i^{(1+\tau)^{k-i}} q^{(1+\tau)^k - 1} \left(f(x_0) - f(x_*)\right),$$

where $\gamma_i \le 1$, $q < 1$, $k > 0$.

Algorithms are effective in the sense of the number of calculations when

$$\Phi(x_k) = x_k - \alpha_k f'(x_k)$$

and also $\Phi(x_k) = x_k - H_k f'(x_k)$, where

$$H_k = \begin{cases} I, & k = 0, \\ x_k - f'(x_{k-1}, u_{k-1})^{-1} f'(x_k), & k \ge 1. \end{cases}$$

For each separate class of problems, you can build a method that is more efficient than basic methods in the sense of the number of calculations.

COLLABORATIVE LAYERED SWARM MOTION PLANNING ARCHITECTURE UNDER DYNAMIC ENVIRONMENT UNCERTAINTY

Harun Bavunoğlu
Ege University, Graduate School of Natural and Applied Science, İzmir, Turkey
bavunogluharun@yahoo.com

Swarm and multi-agent algorithms have been developed over the years searching for solution to problems such as motion planning, collision avoidance, formation controlling, self-aiming and task collaboration. For solution of motion planning problem, many optimization algorithms have been developed and used. For solution of collision avoidance problem, commonly Voronoi Diagrams and Field Force Algorithms have been adapted and used. For solution of formation controlling problem, algorithms based on geometric calculations are developed. For solution of self-aiming problem, reinforcement learning algorithms are commonly used. For solution of task collaboration problem, mostly Hungarian Algorithm and its varieties are applied. At a real swarm environment, all these problems are faced together and have to be concerned together.

This research presents a collaborative iterative layered architecture approach to deal with dynamic environment uncertainty by planning multi-agent motion. To do that a layered architecture has been proposed. First layer is to sense dynamic and static obstacles locally and stay at safe distance by controlling orientation and velocity vector. Second layer is to estimate dynamic obstacle velocity vector and related position covariance to be able to use in first layer in next iteration. Third layer is to share own environmental features (static and dynamic obstacles) and collect from others in swarm. Fourth and last layer is to self-organized destination allocation for collision free path planning. As a proof of concept, a simulation framework for embedded systems has been developed.

References

1. Huang, S.-K., Wang, W.-J., Sun, C.-H. (2021). A Path Planning Strategy for Multi-Robot Moving with Path-Priority Order Based on a Generalized Voronoi Diagram. *Appl. Sci*., 11, 9650.

2. Hüttenrauch, M., Sosic, A., Neumann, G. (2019). Deep Reinforcement Learning for Swarm Systems. *Journal of Machine Learning Research,* 20, 1-31.

OPTIMIZATION PROBLEMS IN PLAYING SPORTS

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

We consider optimization problems of building optimal game strategies according to the criteria of maximizing the probabilities of winning in game sports. The optimal strategies in tennis matches turn out to be close to the optimal solutions of the problems of antagonistic games in the form of mixed optimal solutions. The modern mathematical science of optimization achieves significant results in search for optimal mathematical models and optimal game strategies. In this direction we build more adequate mathematical models and algorithms for finding game strategies with higher winning probabilities. We optimize each subsystem of the mathematical model: for maximizing the winning probabilities of antagonistic games we find saddle points on an admissible set of mixed strategies; for building optimal control of dynamic processes we use the principle of optimality (a sufficient condition for optimality in dynamic programming problems) and the maximum principle (a necessary condition for optimality in problems of the mathematical theory of optimal program control). Adequate mathematical models help us to discover new objective cause-and-effect relationships and as well help us to identify the most important causal factors and focus more attention on what is more important for winning. The important causal factors in tennis games include random variables of power and accuracy of serves, power and accuracy of forehand and backhand, as well as selected game strategies in conditions of geometric and probabilistic incomplete data. The report analyzes the subsystems of the constructed mathematical model, studies the geometric and probabilistic characteristics of incomplete data, and builds robust algorithms for optimizing game strategies. The obtained data on optimized strategies of the tennis game also open up additional opportunities for increasing the efficiency of training processes with the parallel extraction of imported additional information about incomplete data in mathematical models of tennis games.

CONTROLLING THE MOVEMENT OF MANY OBJECTS

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

In this work we solve the tasks of optimal control of moving objects under the action of resistance forces R_i, gravitational forces G_i and controlled traction forces F_i, $i=1,2,\ldots,n,$ which depend on the vector variables x_i (t) of the phase spaces of moving objects. Objects and from the corresponding variables at time t of the local characteristics $S\left(x_i\left(t\right),t\right), W\left(x_i\left(t\right),t\right)$ of the environment and from the spatial geometric H_i characteristics of moving objects. The optimization tasks of building optimal phase trajectories according to complex optimality criteria are considered, taking into account the energy costs

$$E_i=\int_{t_i}^{T_i} e_i\left(F_i(x_i\left(t\right),u_i\left(t\right))\right)dt$$

for the required movements i-th object and time $\left(T_i-t_i\right)$ in the presence of phase restrictions $h_{ij}\left(H_1,\ldots,H_n,x_1\left(t\right),\ldots,x_n\left(t\right)\right)\geq 0,$ $i,j=1,2,\ldots,n$ related to the geometric characteristics of moving objects. Taking into account that the presence of such phase restrictions significantly complicates the search for optimal controls $u_i\left(t\right),$ $i=1,2,\ldots,n$, we introduced additional restrictions with sets X allocated to the phase space, in which the search for the optimal control is carried out on admissible controls in selected sets of admissible parametric control functions, for which the search for optimal parameter values is carried out according to numerical algorithms, which are practically implemented using the methods of conditional gradients and the maximum principle. Increasing the efficiency of calculating optimal phase trajectories is achieved by moving from the space of controls (the space of vector functions $u\left(t\right)=\left(u_1\left(t\right),\ldots,u_n\left(t\right)\right)$ to the space of phase trajectories

$x(t) = (x_1(t), \ldots, x_n(t))$ with the construction of extreme solutions (maximizers of the Hamiltonian of the controlled system) on the set of phase trajectories $x(t)$.

TO CONSTRUCTION OF EXTREME TRAJECTORIES OF CONTROLLED SYSTEMS

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

We consider problems of working models of controlled algebraic-integral-differential systems optimization to design methods of constructing extremal trajectories of controlled systems. Complex tasks of building optimized mathematical and computer models of controlled systems together with simultaneous or parallel construction of optimized system controls are urgent tasks of modern scientific research. In the process of solving practical problems, difficulties often appear, which are usually associated with the large dimension of the phase spaces of the controlled systems, the nonlinearity of the systems of differential equations and equations with partial derivatives and more complex algebraic integro-differential equations, as well as the multi-extremity or multi-criteria optimization problem. The growing power of modern computing technology and advances in the development of numerical methods for the optimization of large systems open the possibility of building algorithms for complex optimization of models together with the optimization of control of complex systems of increasingly large dimensions. In this direction, we offer methods for building algorithms for the optimization of controlled systems, which are focused on finding extreme solutions of complex controlled systems, complex systems of algebraic integro-differential equations, and some controlled subsystems in boundary value problems of mathematical physics. Increasing of the constructed algorithms efficiency is achieved by the implementaition of fast-converging interior point methods and optimized polynomial approximations of phase trajectories based on the use of consistent high order approximations of the controlled system trajectories.

THE VOTING SYSTEM IN ONLINE PLATFORM "ACADEMIC COUNCIL"

O. Bilyk, I. Vergunova
Taras Shevchenko National University of Kyiv, Ukraine
alexwhitecorp@gmail.com, vergunova@bigmir.net

Consider the online platform "Academic Council" developed for use at meetings of the Academic Council. It provides the opportunity to conduct a secret ballot and process its results in real time. Based on the obtained voting results, the system can automatically form the minutes of the counting commission and the relevant parts in the general minutes of the meeting with resolutions based on the voting results.

At the meeting, after discussing the candidates for members of the counting commission, the administrator (the Secretary) on the page "Participants" in the drop-down menu records the appointment of the chairman commission and two other members of the commission. After these actions, the members of the counting commission will receive notifications in the individual notification center. In considering the issue of voting, the Secretary must initiate the voting process. Then all members of the Council can vote in a special window that opens automatically. The Sensus protocol is used in the system to conduct voting and process its results in real time. Using this protocol when receiving an encrypted message from a participant who has voted, allows you to immediately add this message to the list of published results. The signed ballot is returned to the voter as a receipt. As a result, we can immediately see how many participants voted and the current results. Therefore, all members of the Council are provided with dynamic information on the voting process and its results on the meeting page.

After the meeting, the Secretary may generate the minutes, in which the results of voting and decisions on them will be automatically placed according to the template. Decisions will be formed in accordance with the provisions of the University Statute regarding the decision on the presence of a quorum and the adoption of an approving decision. The minutes will be on the page of the meeting. To create files on the template developed a special template engine with the syntactic approach (as in Thymeleaf). The template code is written to a .doc file with the desired stylization, which is saved when processing the tem-plate. Dynamic data is written using the created context in which the subject area model objects are placed. Therefore, in the created template we can use the basic classes of the programming language for data processing.

OPTIMIZATION PROBLEMS FOR RETRIAL QUEUES WITH CHANGEABLE SERVICE RATE

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

We are dealing with a retrial queue of $M/M/1/\infty$ type (see. [1], [2]) with intensity λ of the input Poisson flow of the primary calls, and ν is a parameter of the repeated calls. It is supposed the number of places on the orbit to be equal to $m<\infty$. The parameter of the service time is defined as follows: if at the moment, when a customer (repeated or primary) hits the server, j customers are in the system, then the service time of that customer follows an exponential distribution with parameter μ_j. So, in contrast to the classic systems, we are dealing with the case when service time depends on the number of the customers in the system.

Let $\xi(t)$ stand for the number of the customers on the orbit at the instant *t*. If at that moment the server is busy with the service and its time distribution has parameter μ_i, $i \geq 1$, we say that the server is in the phase *i*. If at the moment *t* server is free, we say that it is in the phase *i*=0. Let $\eta(t) \in \{0,1,2,\ldots,m+1\}$ denote the phase of the server at the time *t*. The process $(\eta(t), \xi(t))$ is a homogeneous Markov process with $E = \{(i,j), j \geq 0,\ 0 \leq i \leq j+1\}$ as a state space.

The probabilities

$$\pi_{0j} = \lim_{t\to\infty} P\{\eta(t)=0, \xi(t)=j\},\ \pi_{1j} = \lim_{t\to\infty} P\{\eta(t)\geq 1, \xi(t)=j\}$$

describe the phase of the server and the number of customers on the orbit in the steady-state regime.

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

References

1. Falin G.I., Templeton J.G.C. Retrial queues. – London Chapman & Hall, 1997. – 331 p.
2. Artalejo J.R., Gomez-Corral A. Retrial Queueing Systems. – Springer, 2008. – 317 p.

THE DIFFUSION TRANSFER PROCESS IN THE CONTROL TASK

[1,2] Ya. Chabanyuk, [3]A. Nikitin, [2]U. Khimka, [2]O. Stepaniak
[1]Lublin University of Technology, Poland
[2]Ivan Franko National University of Lviv, Ukraine
[3]The National University "Ostroh Academy"
ulyana.himka@gmail.com, anatolii.nikitin@oa.edu.ua,
y.chabanyuk@pollub.pl, oleh.stepaniak.real.work@gmail.com

Consider the control task for the diffusion transfer process in the scheme series with small parameter $\varepsilon > 0$ in the form [1]:

$$dy^{\varepsilon}(t) = a(y^{\varepsilon}(t), x(t/\varepsilon))dt + \sigma(y^{\varepsilon}(t), x(t/\varepsilon), u^{\varepsilon}(t))dw(t), \qquad (1)$$

and the stochastic optimization procedure for the control $u^{\varepsilon}(t)$ in the form:

$$du^{\varepsilon}(t) = \alpha(t)\nabla_{\beta(t)}G(y^{\varepsilon}(t), x(t/\varepsilon), u^{\varepsilon}(t))dt, \qquad (2)$$

where $y^{\varepsilon}(t)$ - the transfer process, $x(t)$ - semi-markov switching process

$$\nabla_{\beta(t)}G(y^{\varepsilon}(t), x(t/\varepsilon), u^{\varepsilon}(t)) = (G(y,x,u+\beta(t)) - G(y,x,u-\beta(t)))/\beta(t)$$

Theorem. The copmensating operator $\boldsymbol{L}_t^{\varepsilon}(x)$ [2] in the control task (1), (2) has representation:

$$\boldsymbol{L}_t^{\varepsilon}(x)\varphi(y,x,u) = \varepsilon^{-1}Q\varphi(y,x,u) + \varepsilon^{-1}q(x)\int_0^{\infty} G_x(ds)[D_{t+\varepsilon s}^{t,y}(x) - I]\boldsymbol{P}\varphi(x,y) +$$

$$+\varepsilon^{-1}q(x)\int_0^{\infty} G_x(ds)[D_{t+\varepsilon s}^{t,u}(x) - I]\boldsymbol{P}\varphi(x,u),$$

where Q - the generator of semi-markov process $x(t)$ [2], $G_x(t)$ - the function of distribution of the staying time of the process $x(t)$ at state X [2], $\boldsymbol{P}\varphi(x) = \int_X P(x,dy)\varphi(y)$; $D_{t+\varepsilon s}^{t,y}(x)$, - semigroups with generator $D_{u,t}(x)$, which for the function $\varphi(u) \in C'(R)$ has the following representation: $D_{u,t}(x)\varphi(u) = \alpha(t)\nabla_{\beta(t)}G(y,x,u)\varphi'(u)$.

References
1. Chabanyuk Ya.M., Nikitin A.V., Khimka U.T. Asymptotic Analyses for Complex Evolutionary Systems with Markov and Semi-Markov Switching Using Approximation Schemes. – Wiley-ISTE, 2020. – 240 p.
2. Koroliuk V.S., Limnious N. Stochastic System in Merging Phase Space. – World Scientific, Singapure, 2005.

PRINCIPLE OF TIME DILATION IN GAME PROBLEMS OF CONTROL

A.O. Chikrii, G.Ts. Chikrii
Glushkov Institute of Cybernetics NAS of Ukraine
g.chikrii@gmail.com

In the mathematical theory of conflict-controlled processes, there is a whole range of fundamental methods for studying controlled processes, operating in conditions of conflict and uncertainty. One of the main problems in this field of science is convergence of the trajectories of opposing parties. For it to be solvable in the finite time, a certain advantage in terms of dynamic control resources is needed in favor of the convergence player. This advantage is in many cases expressed by the Pontryagin condition or its various modifications. In so doing, sometimes the solid part of the cylindrical terminal set is introduced into the condition, sometimes, to suppress the adversary's control resource; it is multiplied by some matrix function with subsequent compensation at the account of the terminal set. In this case, the Pontryagin condition turns into two conditions.

However, neither the classical Pontryagin condition, nor the mentioned modifications do not hold for the oscillatory systems and for the soft landing problems.

In this paper, to solve, among other things, the above problems, a modification of the Pontryagin condition associated with time dilation is used. The idea of this technique was first expressed in [1], [2]. A.Azimov used time dilation for the case of integral constraints on control resources and solved problem of soft meeting for the Pontryagin test example under integral control constraints [3].

In the process of substantiating and developing this technique, in [4], [5] its connection with the transition from a game with complete

information to a game with information delay was established that was used to solve a wide range of problems for processes that are described by second-order systems, in particular the problem of soft meeting and oscillatory processes, in the framework of the Pontryagin's first direct method.

In this paper, this approach is used on the basis of the method of resolving functions [6], [7]. The distinctive side of this method is that it provides a complete justification of the classical rule of parallel pursuit, and also effectively uses the technique of set-valued mappings and their selections in the definition of game constructions, and obtaining meaningful results based on them. Work [8] is a confirmation of this.

References

1. Nikolskii M.S. Application of the first diret method in linear differential games.// Izvestia AN SSSR. – 1972. – Vol.10. – P. 51-56
2. Zonnevend D. On one method of pursuit. //Doklady AN SSSR. – 1972. –Vol.204, no 6. – P. 1296-1299.
3. Azimov A.Ya. On one method of pursuit in linear differential games under integral constraints. // Izvestia.AN SSSR, techn. cyb. – 1974. – № 2. – P. 31–35 (in Russian).
4. Chikrii G.Ts. Principle of time stretching in evolutionary games of approach. //Journal of Automation and Information Sciences. – 2016. – Vol. 48, No.5. – P. 12-26.
5. Chikrii G.Ts. Principle of time stretching for Motion Control in Condition of Conflict. // Advanced Control Systems: Theory and Applications, River Publishers Series in Automation, Control and Robotics. – 2021. – P 53-82.
6. Chikrii A.A. An analytical method in dynamic pursuit games. // Proceedings of the Steklov Institute of Mathematics. – 2010. – Vol. 271. – P. 69-85.
7. Chikrii A.A., Chikrii V.K. Image Structure of Multi-valued Mappings in Game Problems of Motion Control.// Journal of Automation and Information Sciences. – 2016. – Vol. 48, No.3. – P. 20–35.
8. G.Ts. Chikrii, A.O. Chikrii. Principle of time dilation in game problems of dynamics.// Cybernetics and Systems Analysis. – 2022. – Vol. 58, No. 1. – P. 45–54.

INFORMATION TECHNOLOGIES OF TEACHING

Didar Didmanidze, Darejan Geladze, Diana Akhvlediani, Marina Didmanidze, Giorgi Imnaishvili
Batumi Shota Rustaveli State University, Georgia

All new methods used in teaching process always gained great interest at all stages of the development of the human being if they improved and developed teaching concept and forms.

The usage of information technologies, especially interactive multimedia gives us opportunity to supply students teaching material in different ways instead of standard lecture.

The advantages of interactive models, interactive teaching as innovative work are the following: they obviously stimulate and develop students and teachers co-operation, group-work and active relationships. Due to its software and universal nature it's easy to use with office and operational systems.

The basic problem in modern educational system is how and what means must be used to rise quality of education and to lead teaching process in a way which must rise pupil/student's ability of learning.

The usage of multimedia presentations at any stage of the lessons/lectures to present teaching material close with reality is approved. It makes easier to remember and learning of lesson material.

If disadvantages are more than advantages in using technologies as a rule, we must refuse in using them. We mention that the using of teaching interactive multimedia means have a lot of advantages. The basic advantage of the them is that multimedia information is supplied to a lot of listener's both visual and listening organs together and causes their emotional rampage. In this case learning information is perceived and remembered easily.

Negative factors of multimedia means are detected according to the fact at which stage of learning we are using them. The main is to detect and understand these negative sides and control situation in a better way. Our researches proved that the practice of using multimedia in educational process has rising tendency.

These issues are the focused in this paper.

MARKET ECONOMY AND SHIPPING

I. Didmanidze, G. Chachanidze, G. Tsitskishvili, M. Kutchava
Batumi Shota Rustaveli State University, Georgia
Georgian Technical University, Georgia
Batumi Maritime State Academy, Georgia
ibraimd@mail.ru

The process, which is characterized by the intensity of the development of market-economic needs and technical-technological changes, has a more difficult effect on countries that are trying to walk the path of independence and join the economic space of the world's developed countries.

Obviously, the satisfaction of today's needs of the market economy directly or indirectly (in different volumes) depends on the level of development of the supporting branches of the socio-economic program in the country. Among these fields, one of the most important, and one can safely say - even vitally important, is the development of transport and transport routes. Such demand put on the agenda creation of international transport corridors in several countries at the same time, the operation of which would increase the volume and speed of cargo transportation and reduce the cost of transportation.

Statistical analysis shows that oil products are leading among the cargo transported through the transport corridor of Georgia. Petroleum products belong to a special category of cargo. Carrying out transport and cargo operations with regards to petroleum products: reception, storage, loading, transportation, reloading, etc. production technologies of operations are different compared to other cargo types.

In addition to oil products, other cargoes are of vital importance for the socio-economic development of Georgia, the volume of which is increasing day by day, and due to this, it is urgent to start marine transport with maximum load.

Many countries used the transport corridor passing through Georgia. Due to the socio-economic and geopolitical situation of Georgia, the function and requirements of its transport corridor have increased significantly day by day, which is to some extent determined by the shipments made by marine transport.

These issues are the focused in this paper.

ON THE ROLE OF INFORMATION TECHNOLOGIES FOR DECISION MAKING PROCESS IN SOCIAL BUSINESS

Ibraim Didmanidze, Ketevan Zoidze, Nino Putkaradze, Natalia Zoidze
Batumi Shota Rustaveli State University, Georgia
Batumi State Maritime Academy, Georgia
ibraimd@mail.ru

The paper outlines that decision-making is the process by which individuals and groups identify, combine, and integrate Information Technologies in order to choose one of several possible courses of action. In social business, research traditions involve the cognition, affect, and behavior that drive both individual decision-making (including attitudes, beliefs, values, and actions) and group decision-making (including group formation, group preference, performance and influence, social decision schemes, straw poll, social comparison, and groupthink). Although some social businessmen have taken up decision-making as a focused research interest, social business generally is seen as informing the emerging technical data areas of the decision sciences

The conversion to the cognition and an assessment of aesthetic things was outlined by means of the irrational sub-modal perception with distortion of the previous original shape of artwork's existence, where a determinative harmonious part was assigned for the content or the language fact in the institutionalization of the artistic work".

The paper discusses that in everyday life - and especially while interacting with others - decision making situations are highly complex and unstructured. For example, if we want to decide how trustworthy or angry a person is, we have to integrate Information Technologies such as facial expressions and the pragmatics of language. The ability to understand and infer other business peoples' thoughts, feelings, and intentions is referred to as "social cognition" or "theory of mind". Based on this understanding of the mental states of others, we make predictions about their behavior and adjust our own behaviors in response. Furthermore, we use this ability to make judgments as to whether certain business behaviors represent violations of moral or social norms.

These issues are the focused in this paper.

TRENDS IN UNEMPLOYMENT

Manana Didmanidze, Ia Motskobili, Zurab Zakaradze
Georgian Technical University, Georgia
Batumi State Maritime Academy, Batumi, Georgia
Batumi fizika-mathematical public school, Georgia

The inevitable feature of a market economy is the existence of a certain level of unemployment, despite the fact that unemployment is one of the visible indicators of macroeconomic instability in the country. Unemployment causes macroeconomic instability precisely when the level of actual unemployment exceeds the set natural limit.

By preparation of specialists it is necessary to strengthen attention to mastering by concrete methods, procedures and technologies of marketing activity.

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.

Duration of unemployment - The period of unemployment of an economically active person can be different. The most short-term is friction unemployment, which can usually last for weeks or months. Structural unemployment lasts longer than friction.

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.

The main indicators of unemployment are: the number of unemployed; duration of unemployment; unemployment rate; the sex-age structure of unemployed; professional-qualified structure of unemployed; sectoral and territorial structure of unemployed.

The present article deals with all the above issues.

USE OF ARTIFICIAL INTELLIGENCE IN BIOLOGICAL SYSTEMS

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

The application layer of AI is becoming more extensive and deeply integrated with basic sciences, industrial production, human life, social management and cyberspace, which has a profound impact on research in biology. Future generations of Artificial Intelligence (AI) technologies specifically adapted for biological sciences will help enable the reintegration of biology. AI technologies will allow not only to collect, connect, and analyze data at unprecedented scales, but also to build comprehensive predictive models that span various subdisciplines. They will make possible both targeted (testing specific hypotheses) and untargeted discoveries. AI for biology will be the cross-cutting technology that will enhance ability to do biological research at every scale. AI to revolutionize biology in the 21st century much like statistics transformed biology in the 20th century. The difficulties, however, are many, including data curation and assembly, development of new science in the form of theories that connect the subdisciplines, and new predictive and interpretable AI models that are more suited to biology than existing machine learning and AI techniques. Development efforts will require strong collaborations between biological and computational scientists. The time for AI in biology has arrived [1]. There are now sensors, Internet of Things (IoT), and environmental monitors that allow the collection of data at unprecedented scales. Large, heterogeneous datasets at the confluence of multiple information streams are rapidly growing in size. We now have multivariate data across time, space, and biological scales that need to be analyzed in an integrated manner to discover system-wide, multiscale phenomena that can lead us to understand fundamental rules of life and their application to other systems. The AI infrastructure to support these efforts is beginning to emerge. There are now computational capabilities in the form of storage, CPU/GPU computing, and large-scale distributed computing which, combined with the increasing availability of software tools for AI, is enabling the rapid exploration and development of novel techniques and applications. These resources continue to grow and will enable the next generation of AI for the most complex problems in biology.

References
1. Camacho DM *et al.* (2018) Next-Generation Machine Learning for Biological Networks. *Cell* 173:1581–1592.

THE UPPER CONFIDENCE BOUND STRATEGY FOR MULTI-ARMED BANDIT PROBLEM

A. Dzhoha, I. Rozora
Taras Shevchenko National University of Kyiv, Ukraine
andrew.djoga@gmail.com, irozora@knu.ua

We consider the stochastic multi-armed bandit problem with stationary rewards [1]. In this problem, a learner chooses an action i from a finite set $\{1,2,...,N\}$ on each step $t = 1,2,...,T$, where T is a natural number and called the horizon. In return, the stochastic environment samples a reward X_t drawn from a distribution associated with the chosen action i. The parameters of these distributions are unknown to the learner.

The goal of the learner is to maximize the total cumulative reward on a given horizon which is equivalent to minimizing the regret.

In this paper, we analyze the Upper Confidence Bound (UCB) strategy [2] for the learner in the environment, where each action is associated with a Bernoulli distribution. Hence, the reward from the environment on the current step t is $X_i \in \{0,1\}$.

To bound the Bernoulli random variable in the analysis, we use properties of the sub-Gaussian random variables in the tail probability estimation. We show that for the given horizon T the regret R of the UCB strategy satisfies:

$$R(T) \le 2\sum_{i=1}^{N} \Delta_i + \sum_{i=2}^{N} \frac{3\ln T}{\Delta_i},$$

where Δ_i is the difference between the distribution mean of the optimal action (the first one in our example) and the distribution mean of action i.

References
1. Bubeck S., Cesa-Bianchi N. Regret analysis of stochastic and nonstochastic multi-armed bandit problems // Foundations and Trends in Machine Learning. – 2012. – Vol. 5(1). – P. 1–122.
2. Auer P., Cesa-Bianchi N., Fischer P. Finite-time Analysis of the

Multi-armed Bandit Problem// Machine Learning. – 2002. – Vol. 47(2). – P.235-256.

ON THE REQUIREMENTS FOR THE CONSTRUCTION OF VIRTUAL COMPONENTS OF COMPUTER SYSTEMS FOR SCIENTIFIC RESEARCH AND SEMI-NATURAL MODELING

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

In the process of creating modern complex objects, it becomes necessary to build various typical components of computer systems to provide hardware and informational support for solving user tasks and problems when automating scientific research or semi-natural modeling of the elements of these complex objects. At the same time, there is a need to ensure the joint uninterrupted operation of components in real time, optimal duplication of communication channels and an appropriate level of security.

A preliminary list of requirements for typical subsystems of an intelligent system for semi-natural modeling and control of its individual components, with complex virtualization of elements at different levels, has been developed.

In general, such typical components allow flexible creation of virtual information subsystems and virtual workplaces for typical or non-standard tasks, with the possibility of convenient visualization of the required technological process.

Modularity of construction and complex virtualization of components at different levels of the system allows any component (virtual sensor, model, virtual device, subsystem, etc.) to be treated using standard algorithms and procedures. It also provides the construction and configuration on the same set of control objects of several virtual information systems for different users or for solving various typical tasks.

When creating components, modern personal software and hardware are used, in particular, for working with wireless communications.

The main conceptual approaches to the construction and options for the architectural and structural organization of typical components and

systems for semi-natural modeling, collection and transmission of information also make it possible to use them to create complex simulators for personnel servicing complex objects. This will provide the ability to reproduce or duplicate the behavior of real complex systems (objects) without interfering with the operation of the objects itself.

THE MULTIPLICITY OF ZEROS OF THE CHARACTERISTIC FUNCTION OF THE BOUNDARY VALUE PROBLEM OF THE DIRAC OPERATOR

A.G. Ferzullazadeh
Lankaran State University, Azerbaijan
abid.ferzullazade@mail.ru

Consider in $[0,\pi]$ the boundary value problem generated by the canonical Dirac equation [1]

$$BY'(x)+Q(x)Y(x)=\lambda Y(x), \tag{1}$$

and the nonseparated boundary conditions

$$A_0Y(0)+A_1Y(\pi)=0 \tag{2}$$

where $B=\begin{pmatrix}0 & 1\\ -1 & 0\end{pmatrix}$, $Q(x)=\begin{pmatrix}p(x) & q(x)\\ q(x) & -p(x)\end{pmatrix}$, $Y(x)=\begin{pmatrix}y_1(x)\\ y_2(x)\end{pmatrix}$, $A_0=\begin{pmatrix}\alpha\lambda+\beta & 1\\ -\overline{\omega} & 0\end{pmatrix}$, $A_1=\begin{pmatrix}\omega & 0\\ \gamma & 1\end{pmatrix}$, $p(x),q(x)\in W_2^1[0,\pi]$, λ is a spectral parameter, α,β,γ are real numbers, ω is a complex number and $\alpha\omega\neq 0$.

The general solution of equation (1) has the form

$$Y(x,\lambda)=M_1C(x,\lambda)+M_2S(x,\lambda),$$

where M_1 and M_2 is an arbitrary constant, and $C(x,\lambda)=\begin{pmatrix}c_1(x,\lambda)\\ c_2(x,\lambda)\end{pmatrix}$

and $S(x,\lambda)=\begin{pmatrix} s_1(x,\lambda) \\ s_2(x,\lambda) \end{pmatrix}$ are solutions to equation (1) satisfying the initial conditions

$$C(0,\lambda)=\begin{pmatrix} 1 \\ 0 \end{pmatrix},\ S(0,\lambda)=\begin{pmatrix} 0 \\ 1 \end{pmatrix}.$$

Using the identity

$$c_1(x,\lambda)s_2(x,\lambda)-c_2(x,\lambda)s_1(x,\lambda)\equiv 1,$$

one can easily show that the characteristic function of the problem (1),(2) has the form

$$d(\lambda)=2\operatorname{Re}\omega-c_2(\pi,\lambda)-\gamma c_1(\pi,\lambda)+|\omega|^2 s_1(\pi,\lambda)+$$
$$+(\alpha\lambda+\beta)\left[s_2(\pi,\lambda)+\gamma s_1(\pi,\lambda)\right].$$

Theorem. If $\alpha<0$, then the characteristic function $d(\lambda)$ cannot have zeros of order greater than 2, i.e., if $d(\lambda_0)=\dot{d}(\lambda_0)=0$ then $\ddot{d}(\lambda_0)\neq 0$.

Note that other properties of the spectrum of this problem are studied in the paper [2-4].

References

1. Gasymov M.G., Levitan B.M. The inverse problem for the Dirac system (in Russian) // Dokl. Akad. Nauk SSSR. – 1966. – Vol. 167. – № 5. – P. 967-970.
2. Ferzullazadeh A.G., Nabiev I.M. Some properties of the spectrum of the Dirac operator with a spectral parameter in the boundary condition // Proc. of Institute of Math. and Mech. of NAS of Azerbaijan. –2020. – Vol. 46(2). –P. 189-196.
3. Ferzullazadeh A.G. On the multiplicities of the eigenvalues of the Dirac operator (in Azerbaijani) // Journal of BEU, Mathematics and Computer Science. –2020. –Vol. 4(2). – P. 111-119.
4. Ferzullazadeh A.G. Solution algorithm of the inverse spectral problem for Dirac operator with a spectral parameter in the boundary condition // Operators and Matrices. –2022. –Vol. 16(1). – P. 113-122.

NONLINEAR ELLIPTIC EQUATIONS WITH *BMO* COEFFICIENTS IN NONSMOOTH DOMAINS IN GENERALIZED MORREY SPACES

T. S. Gadjiev
Institute of Mathematics and Mechanics, Azerbaijan
tgadjiev@mail.az

We obtain the generalized Sobolev-Morrey spaces estimate for weak solutions of a boundary value problem for nonlinear elliptic equations with *BMO* coefficients in nonsmooth domains. We investigate regularity of the weak solutions in generalized Morrey spaces. The nonlinearity has sufficiently small *BMO* seminorm and the boundary of the domain is sufficiently flat.

EXISTENCE AND NONEXISTENCE OF GLOBAL SOLUTIONS FOR NONLINEAR PARABOLIC EQUATIONS

T.S. Gadjiev, R.A. Rasulov
Institute Mathematics and Mechanics Azerbaijan.
Azerbaijan Architecture and Construction university, Azerbaijan
Sheki Branch Azeribajian Pedaqogical university, Azerbaijan
tgadjiev@mail.az, rasulovrafiq@yahoo.com

Let be a bounded domain in *Rn* with smooth boundary, *p* a real number p>2 and *a* a nonnegative real number. In this paper we consider the initial-boundary value problems for nonlinear parabolic equations.

In a recent work, Fujita gave existence and nonexistence theorems for global solutions of the heat equation.

In this paper our purpose is to obtain analogous results for the nonlinear problem

1) in some conditions the problem for p and initial functions,problem has global (nonnegative) solutions belong to some Sobolev space.

2) in some conditions for sufficiently small (nonnegative) initial unction the problem has a global (nonnegative) solution. If initial function is nonnegative and large enough, the solution blows up in a finite time.

THE UNIFORMLY PARABOLIC EQUATIONS OF HIGHER ORDER WITH DISCOUNTINUOUS DATA IN GENERALIZED MORREY SPACES AND ELLIPTIC EQUATIONS IN UNBOUNDED DOMAINS

T.S. Gadjiev, K. Suleymanova
Institute of Mathematics and Mechanics of NAS of Azerbaijan, Azerbaijan
tgadjiev@mail.az, ksuleymanova@mail.ru

We study the regularity of the solutions of the Caushy-Dirichlet problem for linear uniformly parabolic equations of higher order with vanishing mean oscillation (VMO) coefficients. We prove continuity in generalized parabolic Morrey spaces of sublinear operators generated by the parabolic Calderon-Zygmund operator and by the commutator of this operator with bounded mean oscillation (BMO) functions. The strong solution belongs to the generalized Sobolev-Morrey space is obtained. Also we consider elliptic equation in unbounded domains.

DEVELOPMENT OF THE FUZZY ALGORITHMS FOR THE RISK ASSESSMENT

Yusif Gasimov, Asif Pashayev
Azerbaijan University, Baku, Azerbaijan
yusif.gasimov@au.edu.az, asif.pashayev@au.edu.az

The problem of the rational route of transportation and the choice of vehicles based on various criteria in logistics is one of the urgent issues. The question of choosing a rational option when making decisions in the process of solving various complex problems not blindly, but on the basis of the established mathematical model is a priority of this area. Choosing a rational option from possible alternatives containing various criteria for the strategies of the logistics centers is considered as a principle issue. The use of traditional mathematical methods, including mathematical statistics, probability theory, as well as classical optimization methods, is practically not effective in solving the problem of the use of analysis and synthesis for the selection of rational options in transport transportation. In the absence of the classical mathematical apparatus, the complexity of the decision-making process for choosing a rational option among alternatives makes it possible, and sometimes even necessary, to process high-quality expert information.

In this paper decision-making algorithms for choosing rational option based on expert information among transport alternatives are developed. For this purpose the corresponding multicriteria optimization problem in fuzzy statement is investigated, specific algorithms for constructing membership functions are given.

THE FINITE-DIFFERENCE METHOD FOR SOLVING THE OPTIMAL CONTROL PROBLEM FOR THE LINEAR NONSTATIONARY QUASI OPTICS EQUATION WITH A SPECIAL GRADIENT TERM

N.S. Ibrahimov[1], G. Yagub[2], U.M. Farzaliyeva[3]
[1,3]Lankaran State University, Azerbaijan,
[2]Kafkas University, Turkey
natiq_ibrahimov@mail.ru, gabilya@mail.ru, ulker-salayeva@mail.ru

We consider the optimal control problem for the linear nonstationary quasi optics equation with a special gradient term of finding the minimum of functional:

$$J(v)=\beta_0\left\|\psi(.,T,.)-y_0\right\|^2_{L_2(\Omega_L)}+\beta_1\left\|\psi(.,.,L)-y_1\right\|^2_{L_2(\Omega_T)} \quad (1)$$

on the set:

$$V\equiv\left\{v=(v_0,v_1),\ v_s\in L_2(0,l),s=0,1,\left|v_0(x)\right|\le b_0,\right.$$
$$\left.0\le v_1(x)\le b_1,\overset{0}{\forall}x\in(0,l)\right\}$$

under conditions:

$$i\frac{\partial\psi}{\partial t}+ia_0\frac{\partial\psi}{\partial z}-a_1\frac{\partial^2\psi}{\partial x^2}+ia_2(x)\frac{\partial\psi}{\partial x}+a(x)\psi$$
$$+v_0(x)\psi+iv_1(x)\psi=f(x,t,z),(x,t,z)\in\Omega, \quad (2)$$

$$\psi(x,0,z)=\phi_0(x,z),(x,z)\in\Omega_L, \quad (3)$$

$$\psi(x,t,0)=\phi_1(x,t),(x,t)\in\Omega_T, \quad (4)$$

$$\psi(0,t,z)=\psi(l,t,z)=0,(t,z)\in Q, \quad (5)$$

where $i=\sqrt{-1}$ - imaginary unit, $l>0, T>0, L>0$, $a_0>0$, $a_1>0$, $b_1>0, b_2>0, \beta_0\geq 0, \beta_1\geq 0$, are given numbers, $\beta_0+\beta_1\neq 0$; $0\leq x\leq l,\ 0\leq t\leq T, 0\leq z\leq L,\ \Omega_{tz}=(0,l)\times(0,t)\times(0,z),\ \Omega=\Omega_{TL}$, $\Omega_L=(0,l)\times(0,L),\ \Omega_T=(0,l)\times(0,T), Q=(0,T)\times(0,L);\ \psi(x,t,z)$ - is a wave function, $a(x), a_2(x)$ are measurable real-valued functions that satisfy the conditions:

$$0\leq a(x)\leq \mu_0, \overset{0}{\forall}\in(0,l), \mu_0, \mu_1=const>0\ ; \qquad (6)$$

$$0\leq a_2(x)\leq \mu_1, \left|\frac{da_2(x)}{dx}\right|\leq \mu_2,\ \overset{0}{\forall} x\in(0,l), \mu_1, \mu_2=const>0\,; \quad (7)$$

$f(x,t,z), \varphi_0(x,z), \varphi_1(x,t), y_0(x,z), y_1(x,t)$ are given complex-valued functions satisfying the conditions:

$$f\in W_2^{0,0,1}(\Omega),\ \ \phi_0\in \overset{0}{W}{}_2^{2,1}(\Omega_L),\ \ \ \varphi_1\in \overset{0}{W}{}_2^{2,1}(\Omega_T),$$
$$y_0\in W_2^{1,1}(\Omega_L), y_1\in W_2^{1,1}(\Omega_T); \qquad (8)$$

the symbol $\overset{0}{\forall}$ means “for almost everywhere” .

In this work, we will study the issue of applying the difference method to solving the optimal control problem for a linear non-ststionary quasi-optics equation with a special gradient term, when the controls are bounded measurable coefficients. In doing so, we will establish estimates fort he convergence of difference approximations with respect to the functional $[1,2]$.

References

1. Искендеров А.Д., Ягубов Г.Я., Мусаева М.А. Идентификация квантовых потенциалов. – Баку, Чашыоглу, 2012. – 552 с.

2. Ибрагимов Н.С. О сходимости разностного метода решения задачи идентификации для нестационарного уравнения квазиоптики // Научные Труды Азерб. техн. ун-та. Сер. фундаментальных наук. – 2010. – № 4. – С. 54-60.

LYAPUNOV FUNCTIONS AND SYSTEM OF LINEAR DIFFERENCE EQUATIONS WITH RANDOM MARKOV COEFFICIENTS

M. Guckert[1], Yu.V.Shusharin[2], S.V. Degtyar[2]
[1]Technische hochschule mittelhessen, Germany
[2]Kyiv National Economic University named after Vadym Hetman, Ukraine
michael.guckert@mnd.thm.de, shusharin@meta.ua

The study of the stability of solutions using Lyapunov functions is one of the most important methods.

A system of linear difference equations with random Markov coefficients is considered.

$$X_{n+1} = A(\zeta_n)X_n, \quad \det A(\theta_k) \neq 0, \ (k = 1,...,q), \quad \dim X_n = m. \quad (1)$$

where ζ_n - Markov chain taking the values $\theta_1,...,\theta_q$ with probabilities

$$p_k(n) = \mathrm{P}\{\zeta_n = \theta_k\}, \ (k = 1,...,q).$$

We assume that the probabilities satisfy the system of difference equations

$$p_k(n+1) = \sum_{s=1}^{q} \pi_{ks} p_s(n), \ (k = 1,...,q), \quad (2)$$

where the coefficients π_{ks} $(k,s = 1,...,q)$ are the conditional probabilities of the transition from state $\zeta_n = \theta_s$ to state $\zeta_{n+1} = \theta_k$ and satisfy the following conditions:

$$\pi_{ks} \geq 0 \ (k,s = 1,...,q), \ \sum_{k=1}^{q} \pi_{ks} = 1 \ (s = 1,...,q).$$

Further, everywhere for the vector $X = (x_1,...,x_m)^*$ we use the Euclidean norm, which is determined by the formula:

$$\|X\|^2 = XX^* = \sum_{s=1}^{m} |x_s|^2.$$

When studying the stability of solutions to the system of equations (1), it is difficult to give a convenient definition of the concept of stability. A definition was proposed, which turned out to be the most convenient for practice, and some stability theorems were proved.

Lyapunov functions

$$\upsilon_s(n,X)=\sum_{j=n}^{\infty}< w(j,X_j,\zeta_j)\big|X_n=X,\zeta_n=\theta_s>,\ (s=1,..,q;\quad n=0,1,2,...)\quad (3)$$

are considered and found the values of the functional

$$\upsilon=\int\limits_{E_m}\sum_{s=1}^{q}\upsilon_s(0,X)\,f_s(0,X)dX,\ \ dX=dx_1...dx_m,\qquad (4)$$

where $f_s(0,X)$, $(s=1,..,q)$ - partial distribution densities of a system of random variables (X_0,ζ_0). Functions $\upsilon_s(n,X)$ $(s=1,..,q)$ depend only on the type of functions $w_s(n,X)$ $(s=1,..,q)$, on the values of the Markov chain ζ_n $(n=0,1,2,...)$, from the values of the matrices $A_s=A(\theta_s)$, $(s=1,..,q)$.

The existence of the Lyapunov function $\upsilon_s(n,X)$ is considered, which satisfy the system of functional equations

$$\upsilon_s(n,X)=w_s(n,X)+\sum_{l=1}^{q}\pi_{ls}\upsilon_l(n+1,A_sX),\ \ (s=1,..,q;\quad n=0,1,2,...),\quad (5)$$

References

1. Valeev K.G., Karelova O.L., Gorelov V.I. Optimization of linear systems with random coefficients. – M., izd. RUDN, 1996. – 258 p.
2. Kats I.Ya., Krasovsky N.N. On the stability of systems with random parameters. // Applied Mathematics and Mechanics. – 1960. – N5. – P. 809-823.
3. Nakonechnyi O. G., Demidenko S.V., Shusharin Yu.V. Guaranteed estimates of the mean of random sequences.// Visnik Taras Shevchenko National University of Kyiv: Seria fiz.-mat. nauk. – 2014. – №4. – P.204-208.
4. Pashko O.G., Shusharin Yu.V. Solution of linear stochastic equations with random coefficients by Monte Carlo methods. // Visnik Yuriy Fedkovych Chernivtsi National University. Seria: Computerni sistemi ta komponenti. – 2014. – №2. – Tom 5. – P. 21-27.
5. Shusharin Yu.V. Investigation of the stability of solutions of a system of linear stochastic differential equations with Markov coefficients // Obchisluvana ta prikladna matematika. – 2011. – №3. – P.183 – 189.
6. Shusharin Yu.V. Recurrent equations for characteristic functions of solutions of linear difference equations with random coefficients. //Visnik Taras Shevchenko National University of Kyiv: Seria fiz.-mat. nauk. – 2014. – №3. – P. 206-209.

7. Shusharin Yu.V. Algebraic criteria for asymptotic stability of solutions of linear difference equations with random coefficients. Obchisluvana ta prikladna matematika. – 2014. – №1. – P.167-175.

PERPETUITIES IN SIMPLE TERMS AND EXAMPLES

A. Iksanov, R. Kostohryz
[1]Taras Shevchenko National University of Kyiv, Ukraine
iksan@univ.kiev.ua, kostogriz2909@gmail.com

Perpetuities are random series of a special form. These arise in most of natural sciences as well as diverse areas of applied probability. In the first part of the talk we shall discuss relations of perpetuities to other probabilistic objects such as random Lueroth series, decomposable distributions, exponential functionals of subordinators and fixed points of the shot noise transforms. In the second part we shall recall some known results concerning distributional properties of perpetuities such as existence, continuity of distributions and existence of moments. We shall try to avoid heavy probabilistic machinery so that the talk should be accessible to a wide audience. A number of illustrating examples will be given.

FORECASTING OF TRAFFIC CONGESTION USING SIMULATION AND ARTIFICIAL INTELLIGENCE

O. Ivankiv[1], A. Melnychyn[1], M. Kovalyk[2]
[1]Ivan Franko National University of Lviv, Ukraine
[2]Lviv Polytechnic National University, Ukraine
oleh.ivankiv.public@gmail.com, andiy.melnychyn@lnu.edu.ua, mykola.kovalyk.public@gmail.com

One of the most significant aspects of a modern city is its road infrastructure. To make efficient road improvement decisions, city administrations require a large amount of data. Inadequate data can lead to premature decisions that worsen traffic. The development of a new effective and inexpensive way for acquiring information about the state of the city's road infrastructure will significantly decrease expenses while improving the quality of implemented measures.

Two methods for forecasting traffic congestion were developed, the factors that can influence it were investigated, and a study was

conducted to evaluate the accuracy of these methods. The proposed methods use non-temporal data (the structure of the road network and the positioning of road objects; in the future, the value of area will also be considered) and are thus independent of any other parameters, making them suitable for use in further analyses. The simulation method is developed with the main goal of generating numerous training samples for AI. One simulation takes place in three stages: 1. Map generation, 2. Simulation iteration, 3. Data export. The generated data is then used to train a layered artificial neural network that takes road structure as an input, and generates congestion data. Use of artificial intelligence allows to considerably speed up the process of traffic congestion prediction.

For the first time, methods for forecasting traffic congestion, which help to determine the effectiveness of road network, using non-temporal data have been developed.

References

1. Akhtar M. A Review of Traffic Congestion Prediction Using Artificial Intelligence. // Journal of Advanced Transportation. – 2021. – 18 p.
2. Kumar N. Applications of deep learning in congestion detection, prediction and alleviation A survey. – Transportation Research, 2021. – 27 p.
3. Bull Alberto, Compilador. Traffic congestion the problem and how to deal with it. – Santiago, 2003. – 198 p.

PARAMETRIC IDENTIFICATION OF THE SIR MODEL OF THE SPREAD OF EPIDEMICS

S.M. Ivanov, M.S. Kostrubina
Taras Shevchenko National University of Kyiv, Ukraine
kostrubina.maria@gmail.com

We considered the SIR model of the spread of epidemics and its approximate general solution, and performed parametric identification. In this model, the population is divided into three conditional groups:

number of susceptible individuals - S, infected - I, recovered and dead - R.

In [1], an approximate solution was presented and adapted to the parametric estimation of model parameters.

Equations for parametric estimation:

$y = b_0 + b_1 t$ and $z = b_0 + b_1 R$, $y = \ln((S_0-R)/S_0)$, $z = \ln((I_0+ S_0-I-R)/S_0)$.

Based on the data downloaded from the resource [2], training and test samples were formed.

Using the method of least squares, the parameters of the obtained equations were estimated and confidence intervals were found with a probability of 95%.

The results are presented in fig. 1:

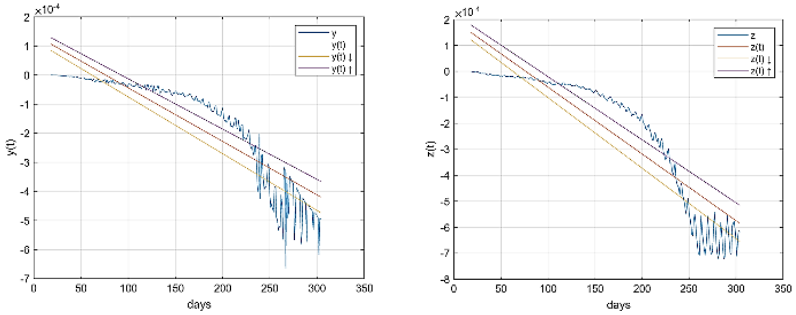

Figure 1 - simulation of results

Conclusion Based on the presented algorithm of parametric identification of the system, an estimate of the parameters was found based on the available statistical data on the incidence of coronavirus in Ukraine. However, the parameters of the model might be strongly affected by vaccination, significant demographic changes and other factors.

References

1. Ivanov S.M. Analytical solution and adaptation to the parameter estimation of the SIR model / S.M. Ivanv// Bulletin of Taras Shevchenko Natinal University of Kyiv. – 2020. – No 4. – P.40-43. (in ukrainian) https://doi.org/10.17721/1812-5409.2020/4.6/

2. Available from: https://covid19.gov.ua/analytichni-paneli-dashbordy (30.10.2021)

PREDICTION OF THE LEVEL OF CO_2 IN KYIV BASED ON THE NARMAX MODEL

S.M. Ivanov, A.H. Subotina
Taras Shevchenko National University of Kyiv, Ukraine
alina_subotina@knu.ua

In the process of creating a NARMAX model [1] for forecasting the concentration of CO_2 in the air, we developed an algorithm for the sequential addition of previous input values (monthly average air temperature $u(t - n_u)$ and carbon dioxide concentration $y(t - n_y)$), and their product. As a result, we obtained a model that is reduced to multiple linear regression, because this model is linear in parameters. The estimated parameters are statistically significant with a probability of 0.95. The training set and testing set were formed on the basis of monthly average CO_2 concentrations and air temperature data downloaded from [2]. The results of modelling on the training set are presented in the figure:

The coefficient of multiple determination R^2=0.96 is statistically significant with a probability of 0.95.

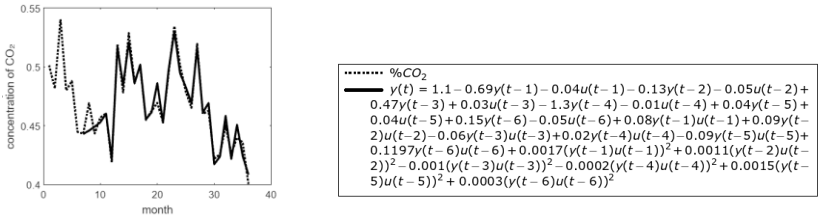

Fig.1 Modelling

Conclusion. The application of the NARMAX model in forecasting the concentration of carbon dioxide gave good results in the quality of the forecast. However, for the further use of this approach, it is necessary to take into account not only air temperature but also man-made factors as external inputs.

References

1. Billings S.A. Nonlinear System Identification: NARMAX Methods in the Time, Frequency, and Spatio-Temporal Domains / S. A. Billings. – Sheffield, 2013. – 576 p.
2. Available from: http://cgo-sreznevskyi.kyiv.ua/index.php/uk/diialnist/klimatolohichna/klimatychni-dani-po-kyievu (06.11.2022)

ON THE INFLUENCE OF FUZZY PERCEPTION OF THE FLOW OF TIME ON THE SOLUTION OF OPTIMIZATION PROBLEMS OF PLANNING

E. Ivohin, L. Adzhubey, P. Vavryk, V. Rets
Taras Shevchenko National University of Kyiv, Ukraine
ivohin@knu.ua, adzhubey@ukr.net, petro.vavryk@gmail.com

One of the approaches for formalizing the representation of time intervals that determine different rates of time counting is the construction of time interval boundaries of two types: exact and guaranteed, for which different approaches are used. In [1], an attempt was made to describe the flow of time in the form of fuzzy quantities of a special type. The representation of fuzzy terms is determined using specific membership functions of some fuzzy numbers, which are built on the basis of a body of knowledge obtained from the repository or on the basis of the results of expert information processing.

Among the tasks in which, in order to find an optimal or effective solution, it is necessary to take into account the factors influencing the emotional state of a person, and, as a result, the rate of perception of the time reference, it is necessary to single out the tasks of time planning. In this paper, we propose to consider further detailing the methodology for formalizing the process of time flow based on fuzzy numbers and its application in solving individual fuzzy optimization problems of time distribution, taking into account the uncertainty associated with the influence of non-uniform rates of time counting.

Examples of the use of fuzzy flow of time for different statements of tasks that arise when determining the order of the set of tasks within a given time interval with or without additional constrains on the execution process are considered. An approach is proposed for the correction of the initial time distribution plans, taking into account different rates of time counting.

A mathematical model of the fuzzy traveling salesman problem is formulated as a problem of finding a route to visit a given number of cities with a minimum travel time with time parameters specified as right fuzzy numbers, the support value in which depends on various external conditions and factors.

References

1. Ivohin E.V. (2021) Formalization of Influence Processes of Fuzzy Time Flow on the Solution to Time Resource Distribution Problems. *Cybernetics and Systems Analysis*, 57(3), p. 363-373.

INFLUENCE OF ACOUSTIC VIBRATIONS OF THE SUBSTRATE OF A HIGH-FREQUENCY GRATING

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

In this article is considered the influence of lattice substrate acoustic high frequency oscillation localization on InP growth, John-Teller type distortion appearance.

The influence is realized bu means of the localization of a lattice substrate high-frequency acoustic longitude oscillation which induces symmetry distortion and John-Teller type degeneration taking off, so modulation of growth space with ultrasound field generated by vibrant substitutional atom, also the substitutional atom degeneration state transformation caused by temperature variation, fluctuation during of the epitaxial growth process.

According to $Jahn-Teller's$ general theory any structure of atoms with degenerated general state of electron system is unstable, except the pure sping degeneration or linear structure of the atoms.

In the mode of acoustic resonance, the shift of iron ion is equal to infinity and occurs perpendicularly to the indium atoms row along the direction <111>. Unharmonism of very power high frequency oscillation of substitutional atom determines the increase of (c) lattice parameter. At the growth temperature the iron ion, being in resonance, involves tighty bounded with it and comparably resting atoms of oxygen and phosphorus, and fostering reduction of the lattice parameter - a_0 at the growth plate. Enthrophy increases and free energy decreases.

Symmetry decrease causes splitting of electronic levels or taking orbital degeneration off. Electrovalence vanies. Several levels are formed, some of deeper disposal. As bigger is the iron nuclei displacement, as greater is splitting.

Increasing growth temperature decreases the substrate lattice symmetry in the acoustic oscillation localization place.

The present article deals with all the above issues.

TOWARDS 5G-ENABLED SMART CITIES: A NOVEL BLOCKCHAIN-BASED FRAMEWORK FOR SECURE SMART CITY APPLICATIONS.

Nazlı Esin Kamaç[1], Bora Buğra Sezer[1,2], Urfat Nuriyev[1,3]
[1]Department of Mathematics, Ege University, İzmir,Turkey
[2]School of Natural and Applied Science, Ege University, İzmir,Turkey
[3]Azerbaijan State Agricultural University, Ganja, Azerbaijan
nazkamac@gmail.com, bora.bugra.sezer@ege.edu.tr, urfat.nuriyev@ege.edu.tr

In recent years, with the development of sensor technologies and the development of electronic circuits suitable for this technology, the Internet of Things (IoT) has emerged as an important innovation for smart cities. In addition, thanks to its superior technical features such as high speed, wide connection, and low latency, 5G (5th generation mobile networks) technology plays an important role in the foundation of smart cities. In smart cities, although IoT-based systems provide many standard solutions, they suffer from privacy, auditability, and security challenges. Blockchain technology is a useful technique that can be used in IoT-based smart cities, thanks to its special features such as decentralized, transparent, and secure. In this study, we propose a blockchain-based smart access framework for a secure and traceable smart city application in 5G-enabled smart cities. The proposed architecture has a minimum transaction load with its off-chain integrated system. In addition, double security is provided by the use of the InterPlanetary File System (IPFS) in the storage of data obtained by the use of existing cryptographic protocols. When we compare aspects the security in the current literature, we can say that the framework gives positive results in terms of competition and supports blockchain-based smart cities development architecture.

References

1. Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. Decentralized Business Review, 21260.
2. B.B.Sezer and U. Nuriyev, "Blockchain Scalability And Distributed Ledger Technologies," Materials II International Scientific Conference for the Information Systems and Technologies Achievements and Perspectives,vol.2, no.2, pp.8-11, 2020.
3. SAMUEL, Omaji, et al. Towards sustainable smart cities: A secure and scalable trading system for residential homes using blockchain and artificial intelligence. *Sustainable Cities and Society*, 2022, 76: 103371.

APPROXIMATE OPTIMAL CONTROL FOR A PARABOLIC SYSTEM WITH PERTURBATIONS IN THE COEFFICIENTS ON INFINITE TIME INTERVAL

Olena Kapustian, Oleksiy Kapustyan, Anton Ryzhov, Valentyn Sobchuk
Taras Shevchenko National University of Kyiv, Ukraine
olenakapustian@knu.ua, kapustyan@knu.ua, ryzhov@knu.ua, v.v.sobchuk@gmail.com

The typical averaging problem may be defined as follows: one considers an unperturbed problem in which the slow variables remain fixed. Upon perturbation, a slow drift appears in these variables which one would like to approximate independently of the fast variables. In [1], the averaging results for ordinary differential equations perturbed by a small parameter are proved. It should be noted that the transition to the averaging parameters can essentially simplify the problem [2].

In this paper, we use this approach to non-linear parabolic system with fast-oscillating (with respect to time variable) coefficients $f\left(\frac{t}{\varepsilon}, y\right)$ on an infinite time interval. We prove [3] that the optimal control of the problem with averaging coefficients can be considered as an "approximately" optimal for the initial perturbed system.

To demonstrate effectiveness of the method we plan to continue research focusing on the practical applications and simulation results using in particular genetic algorithms.

References

1. Lakrib, M.; Kherraz, T.; Bourada, A. (2016) Averaging for ordinary differential equations perturbed by a small parameter. *Math. Bohem*., 141, p. 143–151.
2. Kapustian, O.A., Sobchuk, V.V. (2018) Approximate homogenized synthesis for disturbed optimal control problem with superposition type cost functional. *Stat. Opt. Inf. Comp*., 6, p. 233–239.
3. Kapustian, O.A. Kapustyan, O.V.; Ryzhov, A., Sobchuk, V. (2022) Approximate Optimal Control for a Parabolic System with Perturbations in the Coefficients on the Half-Axis. *Axioms,* 11, 175. https://doi.org/10.3390/axioms11040175

DEVELOPMENT OF WEB-APPLICATION FOR EFFECTIVE BUSINESS MANAGEMENT

Olena Kapustian, Pavlo Stepchenko
Taras Shevchenko National University of Kyiv, Ukraine
olenakapustian@knu.ua, pstep4e23@gmail.com

In this paper, the mathematical model is considered and technical solutions for optimizing business processes are proposed. As a result of modelling it is established that automation and implementation of an effective management system of the company yields the maximization of profits.

As a solution to increase efficiency, the web application is designed and built using the Django framework in Python [3] with a user-friendly interface. The stages of backend development are considered in detail and the user interface is described. We also take into account all possible stages of improving the service to ensure greater functionality. The final product has been implemented.

The developed web application contains services for managing all financial, personnel and other resources of the company and can be used for effective business management and solving business games.

References

1. Kapustian O., Reznichenko I. The optimal control problem with application to business strategy // Proceeding of XX International Scientific-Practical Conference «Shevchenkivska Vesna – 2022», Kyiv, 14.04.2022 (on-line),
URL: https://probability.knu.ua/shv2022/ShV_2022.pdf).
2. Dolenko G. (2011) System Optimization. Applied Problems: educational and methodological textbook // Publishing and Printing Center “Kyiv University”, 77 p.
3. Python 3.10.4 documentation: [Website]. URL: https://docs.python.org/3/.

ON THE INVARIANCE AND UNIQUENESS OF THE SOLUTION OF HERMITE INTERPOLATION PROBLEMS IN EUCLIDEAN SPACE

O. F. Kashpur
Taras Shevchenko National University of Kyiv, Ukraine
olena.kashpur@gmail.com

The problem of system identification based on its response to input signals often arises in applied mathematics. One of the methods for solving this problem is interpolation. Monographs [1] contains fundamentals of general operator interpolation theory in abstract Hilbert and vector spaces. The results of this work are a continuation of the research of the author [2], [3] in Euclidean space.

In the paper, Hermite interpolation problems for the finite-dimensional Euclidean space E_k are expanded in the case when the value of the function and the value of its Gauteox differentials up to the first and up to the second order, respectively, are specified in the interpolation nodes. It is shown that these problems have a unique solution of the minimal norm generated by the Gaussian measure, among all interpolants corresponding to fixed interpolation conditions. The conditions of invariant solvability and the unity of solving these problems are obtained.

It is shown that the minimum norm interpolant is a solution of the Hermite problem under conditions of uncertainty, that is, when the initial information is not sufficient to uniquely determine the interpolation polynomial. All the conditions of the theorems are obtained in terms of the values of the many-variable function and its derivatives and in terms of matrices built according to the system of interpolation nodes. Note that similar results for the Lagrangian interpolation problem for a function of many variables were obtained in [2].

References

1. Makarov V., Khlobystov V., Yanovich L. Methods of operatorinterpolation. – Kyiv, NASU, Inst. of mathematics, v.83, 2010. – 516 p.
2. Kashpur O., Khlobystov V. Invariance and uniqueness of solutions tj polynomial interpolation problems in Euclidean space //Journal of Comp. and Applied Mathematics. – 2015. – 2(119). – P.8 - 14.
3. Khlobystov V., Kashpur O. Hermite interpolant in Hilbert space asymptotically accurate on polynomials// Bulletin of the University of

Kyiv, Series: Physics & Mathematics. – 2005. – № 2. – P. 316 - 323.

INVESTIGATION OF THE SOLUTION OF THE BOUNDARY VALUE PROBLEM FOR ELLIPTIC PARABOLIC EQUATIONS

Mehriban Nurmamed Kerimova
Sheki branch of the Azerbaijan State Pedagogical University, Azerbaijan
kerimova.mexriban@mail.ru

We consider a boundary value problem for degenerate equations with discontinuous coefficients and establish the unique strong solvability (almost everywhere) of this problem in the corresponding weighted Sobolev space. Initial boundary problems for this type of degenerate equations have been by many authors. M.Keldish, Q.Fichera gave the right formulation of such problems and showed their unique strong solution. T.Gadjiyev and his students studied the qualitative properties of solutions of one class elliptic-parabolic equations and showed their unique strong solution.

The purpose of this work at differently previous studies, the following is to prove a unique strong (almost everywhere) solvability of the first boundary-value problem for equation

$$Zu = \sum_{i,j=1}^{n} a_{ij}(x,t)u_{x_i x_j} + \psi(x,t)u_{tt} - u_t = f(x,t) \quad (1)$$

$$u\big|_{\Gamma(Q_T)} = 0 \quad (2)$$

in cylinder $Q_T = \Omega \times (0,T), T \in (0,\infty)$, where $\Omega \subset R^n$ with a boundary $\partial\Omega \subset C^2$. $\Gamma(Q_T) = (\partial\Omega \times [0,T]) \cup (\Omega \times \{(x,t): t = 0\})$ is a parabolic boundary of the domain Q_T, $\psi(x,t)$ and coefficients $a_{ij}(x,t)$ tent to zero.

USING THE INTERNET OF THINGS IN HIL SIMULATION

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

The Internet of things for corporate / branch application - the system of the joint computer networks and the connected industrial (production) facilities with built-in sensors and software for collecting and data exchange, with a possibility of remote control and management in the automated mode, without the participation of the person. The information obtained can be used to prevent unplanned outages, equipment breakdowns, reduce unplanned maintenance and supply chain management failures, thereby enabling the enterprise to operate more efficiently. When processing a vast array of unstructured data, filtering and adequately interpreting it is a priority for enterprises. Such large amounts of data require processing to be used in the decision-making process. Online analysis helps users find the causes of problems faster. Continuous proactive monitoring of key indicators provides an opportunity to identify the problem and take the necessary measures to solve it. Production data is transformed into useful information that is necessary for the safe and rational management of the enterprise. The introduction of network interaction between machines, equipment, buildings, and information systems, the ability to monitor and analyze the environment, the production process, and its state in real-time, the transfer of control and decision-making functions to intelligent systems lead to a change in the "paradigm" of technological development. An important source of data is sensors, a variety of small IIoT devices whose data is used in real-time. Cisco calls this data "data in motion". Example: A networked tire pressure sensor detects that the tire is flat. The sensor communicates with the nearest tow truck. The tow truck arrives at the location precisely determined by the sensor. The main difference between the Internet of things and conventional automated control systems is the amount of data processed. Thanks to this, the user sees the operation of the equipment in real-time. IoT technology uses non-relational (NoSQL) databases. They do not aggregate information that comes from devices but store it in its original form, which allows you to accumulate terabytes of signals for any period of time. Since the data is not aggregated, it is possible to cut by any parameter and apply a new algorithm to historical signals, which allows you to quickly and flexibly work with information.

STABILITY AND CONVERGENCE OF DYNAMIC PROCESSES IN NEURODYNAMICS

D.Ya. Khusainov, A.V. Shatyrko, T.I. Shakotko
Taras Shevchenko National University of Kyiv, Ukraine
d.y.khusainov@gmail.com, shatyrko.a@gmail.com, trachuk_85@ukr.net

The field of knowledge in which neural networks are considered as nonlinear dynamic systems and the main attention is paid to the problems of stability and convergence is called neurodynamics. The mathematical apparatus that describes the processes is a system with a distinguished linear part and a nonlinearity enclosed in some rather small sector. Obviously, for a small value of "weak nonlinearity", the stability of the equilibrium position of the nonlinear system will follow from the asymptotic stability of the linear approximation system. From here, in particular, the convergence of learning processes will follow.

An essential feature that arises in the study of dynamic processes in neurodynamics is the consideration of the aftereffect time.

In this report, we study the stability of Hopfield neural networks that describe dynamic processes in neural networks and build estimates of the convergence of learning processes of neural networks, taking into account the aftereffect.

To study stability, the second method of Lyapunov functions is used with an additional Razumikhin condition [5]. Conditions for the asymptotic stability of the equilibrium position of systems with delay are obtained.

The neuron model proposed in the work ([1], p. 851, fig. 14.7) is considered. It has the form of a system of differential equations

$$\frac{dv_i(t)}{dt} = -a_i v_i(t) + \sum_{j=1}^{n} w_{ij\,j}\varphi\left(v_j(t)\right) + K_j\,.$$

Another model of neurodynamics can be described by a system of the form

$$\frac{dx_i(t)}{dt} = -a_i x_i(t) + \varphi\left(\sum_{j=1}^{n} w_{ij} x_j(t)\right).$$

If the signal processing time is taken into account, then systems of differential-difference equations with delay are used

$$C_i \frac{dy_i\ t}{dt} = -\frac{1}{R_i} y_i\ t\ + \sum_{j=1}^{n} \nu_{ij} \phi_j\ y_j\ t-\tau\ \ + I_k,\ t \geq 0,\ i = \overline{1,n}.$$

The report presents the main results on the study of stability and obtaining estimates of the convergence of neurodynamic processes, obtained by the authors in recent years. The study of stability and convergence is carried out using the second Lyapunov method. For equations with delay, additional conditions of B.S. Razumikhin and the method of Lyapunov-Krasovsky functionals.

References

1. Pisarenko V.G. A new model of the functioning of a living neural network, taking into account the delayed interaction of neurons // Cybernetics and System Analysis, No. 6, 2016. - P. 181-192.
2. Khaykin Simon, Neural networks. Full course. Second edition. - Moscow, Williams Publishing House, 2006. - 1104 p.
3. Khusainov D.Ya., Diblik Y., Bashtinets Ya., Sirenko A.S. Stability, non-uniform in delay, of one weakly nonlinear system with aftereffect // Proceedings of the Institute of Applied Mathematics and Mechanics, V.29, 2015. - P.129-146.
4. D. Ya. Khusainov, Y. Diblik, Ya. Study of the dynamics of one weakly nonlinear system with delay // Problems of Control and Informatics, No. 1, 2018. - P. 22-37
5. Shakotko T.I., Khusainov D.Ya., Sirenko A.S. About one step to achieve the stability of the model of neural networks with a delay by another Lyapunov method // Bulletin of the Taras Shevchenko National University of Kyiv, Series: Physics and Mathematics, v.4, 2014. - P.232-237.

SMALL COUNTS IN NESTED KARLIN'S OCCUPANCY SCHEME GENERATED BY DISCRETE WEIBULL-LIKE DISTRIBUTIONS

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

A nested Karlin's occupancy scheme is a symbiosis of classical Karlin's ball-in-boxes scheme and a weighted branching process. To define it, imagine a deterministic weighted branching process in which weights of the first generation individuals are given by the elements of a discrete probability distribution. For each positive integer j, identify the jth generation individuals with the jth generation boxes. The collection of balls is one and the same for all generations, and each ball starts at the root of the weighted branching process tree and moves along the tree according to the following rule: transition from a mother box to a daughter box occurs with probability given by the ratio of the daughter and mother weights.

Assume that there are n balls and that the discrete probability distribution responsible for the first generation is Weibull-like. Denote by $\mathcal{K}_n^{(j)}(l)$ and $\mathcal{K}_n^{(*j)}(l)$ the number of the jth generation boxes which contain at least l balls and exactly l balls, respectively. We prove functional limit theorems (FLTs) for the matrix-valued processes $\left(\mathcal{K}^{(j)}_{\left[e^{T+\bullet}\right]}(l)\right)_{j,l\in\mathbb{N}}$ and $\left(\mathcal{K}^{(*j)}_{\left[e^{T+\bullet}\right]}(l)\right)_{j,l\in\mathbb{N}}$, properly normalized and centered, as $T\to\infty$. The present FLTs are an extension of the FLT proved by Iksanov, Kabluchko and Kotelnikova (2022) for the vector-valued process $\left(\mathcal{K}^{(j)}_{\left[e^{T+\bullet}\right]}(1)\right)_{j\in\mathbb{N}}$. While the rows of each of the limit matrix-valued processes are independent and identically distributed, the entries within each row are stationary Gaussian processes with explicitly given covariances and cross-covariances. We provide an integral representation for each row. The results obtained are new even for Karlin's occupancy scheme.

References

1. Iksanov A., Kabluchko Z., Kotelnikova V. A functional limit theorem for nested Karlin's occupancy scheme generated by discrete Weibull-like distributions. *J. Math. Anal. Appl.* 507 (2022), no. 2, Paper No. 125798, 24 pp.

REGULARIZATION BY MEANS OF DENOISING IN IMAGING

O. Kravchuk, G. Kriukova
National University of Kyiv-Mohyla Academy, Ukraine
o.kravchuk@ukma.edu.ua, kriukovagv@ukma.edu.ua

Solving modern machine learning tasks requires the development of new methods of solving corresponding inverse problems. The majority of real-world inverse problems are ill-posed and therefore require regularization. For some digital signal processing tasks, such as image de-noising, image restoration, super-resolution, image improvement, the choice of regularization technique is nontrivial, whereas significantly influences the corresponding solution.

In our work we consider a framework for inversion of image transforms. For inverse problem $Ax = y$ we consider Bayesian approach, or maximum a posteriori probability (MAP) estimate, which finds such an x, that maximises the conditional probability $p(x|y)$. According to Bayes rule, it corresponds to maximizing the $p(y|x)p(x)$, or equivalently to minimizing over x the expression $(-\log p(y|x) - \log p(x))$, where first term is usually approximated by loss function, and second one is called regularization term.

In [1] for some given denoiser $D(x, \sigma)$ the Regularization by Denoising via Fixed-Point Projection (RED-PRO) framework applies the regularization $\rho(x) = \alpha x^T [x - D(x, \sigma)]$. It has been shown [1], that Plug-and-Play Prior (PnP) proximal gradient method considered in [2] is a special case of RED-PRO, the convergence of both frameworks to globally optimal solutions has been proven.

References

1. Regev C., Michael E., Peyman M. Regularization by Denoising via Fixed Point Projection (RED-PRO). SIAM Journal on Imaging Sciences. Society for Industrial and Applied Math. 2021. Vol. 14, Is. 3.
2. Boyd S., Parikh N., Chu E., Peleato B., Eckstein J. Distributed optimization and statistical learning via the alternating direction method of multipliers. Found. Trends Mach. Learn. 2011. Vol. 3(1). Pp:1–122.
3. Pereverzyev S. Selected Topics of the Regularization Theory. Springer International Publishing. Cham. 2014.

TO THE QUESTION OF BUILDING A TECHNOLOGICAL SMART SIMULATOR

L. Kurzantseva
Glushkov Institute of Cybernetics NAS of Ukraine
larku@ukr.net

In developed countries, industry transition to the INDUSTRY 4.0 is carried out, SMART Industry, SMART enterprises are formed.

Despite the expansion of production automation and the growth of intellectualization of control systems, there is an increase in accidents due to the fault of operators, which causes irreparable damage, which leads to large economic losses, environmental damage and human casualties. This is due to the traditional approach to the creation of automated control systems, in which the main attention is paid to the development of the latest technical achievements without taking into account the personality of the operator. In order to eliminate these trends, the direction of computer technological simulators is developed, which allows operators of automated process control systems to quickly acquire professional competence. An important factor in the successful work of the operator is his reaction to stress, which occurs taking into account his individual characteristics with psychophysiological, intellectual, emotional tension. However, when analyzing existing simulators, it turned out that they are used only for the training of operators, and issues related to the development of stress resistance in the training process are not considered.

A computer technological SMART simulator is proposed, designed to develop skills in remote work with equipment in the preparation of operators of technological process management systems and objects in specialized training centers for training, and in educational institutions of the technological profile. Its difference from the existing ones is that it provides the operator not only with the maximum approach to the individualization of training, the possibility of acquiring professional competencies, but also expands his individual capabilities, acquires resistance to stress.

The operator will increase the stability of attention and coordination of movements, will be able to quickly make the right decisions, in critical conditions, and thereby reduce the possibility of an emergency, prevent the destruction of expensive equipment and harm to the environment.

At the same time, the efficiency and quality of operator training

will increased, and the reliability and cost-efficiency of the work of technological equipment will be ensured.

ANALYSIS OF STABILITY AND REGULARIZATION OF VECTOR 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

Let's consider the vector problem of optimization the view

$$Q(F_u, X): \ \max\{F(x) \mid x \in X\},$$

where $F(x) = (f_1(x),...,f_\ell(x))$, $\ell \geq 2$, $X \neq \varnothing$, X – set of arbitrary structure, possibly discrete, $X \subset R^n$, $f_i(x) = \langle x, D_i x\rangle + \langle c_i, x\rangle$, $c_i \in R^n$, $D_i \in R^{n\times n}$, $i \in N_\ell = \{1,...,\ell\}$. $S\ell(F,X)$ and $P(F,X)$ are sets of optimal solutions of the problem $Q(F_u, X)$.

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 $Q(F_{u(\delta)}, X)$ 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 $Q_{Sl}(F_u, X)$ ($Q_P(F_u, X)$) 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

$$O_\varepsilon(B) = \left\{ x \in R^n \;\middle|\; \inf_{y\in B} \|x - y\| < \varepsilon \right\}.$$

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

New results have been obtained related to stability and regularization of vector optimization problems under possible perturbances of input

data of a vector criterion consisting of quadratic or linear functions. The stability of problems with quadratic criteria for finding Slater-optimal solutions is proved. In the case of Pareto optimization, an approach to regularization of problems with linear criterion functions has been developed.

References

1. Lebedeva T.T., Semenova N.V., Sergienko T.I. Stability and regularization of vector optimization problems with possible perturbations of criteria. // *Kibernetyka ta systemnyy analiz.* – 2022. – 58(5). – P. 57–63.

THE STRUCTURE OF TYPICAL ONE-PARAMETER BIFURCATIONS OF FLOWS ON A ONE-CONNECTED TWO-DIMENSIONAL REGION

M. Loseva, A. Prishlyak
Taras Shevchenko National University of Kyiv, Ukraine
mv.loseva@gmail.com, prishlyak@yahoo.com

Morse-Smale flows are structurally stable flows on compact oriented surfaces. The set of such flows is everywhere dense in the space of all flows. The structure of such flows on surfaces with the boundary is described in [1–6].

A flow has the codimension 1 if it admits a typical one-parameter bifurcation. A flow is optimal if it has the smallest number of singularities among all flows of the same type. There at 17 types of flow bifurcation on a compact planar region.

Theorem. The following structures of codimension 1 optimal flows with internal degenerate singularities exist on a two-dimensional one-connected region:

SN (with a saddle knot) – two (opposite);
HC (with a homoclonic cycle) – two;
AH (Andronov-Hopf) – two;
SL (with a saddle loop) – two;
PC (with a parabolic cycle) – two;
SC (with saddle connections) – six.

With degenerate singularities on the boundary, there exist the following optimal flows structures:

BSN (boundary saddle-knot) – two;
BHC (boundary saddle-knot with a homoclinic loop) – two;

BDS (boundary double saddle) – three;
BDSH (boundary double saddle with homoclinic loop) – one;
HN (semi-boundary saddle-knot (knot)) – two;
HS (semi-boundary saddle-knot (saddle)) – four;
BDN (double knot on the boundary) – two;
BDNH (double knot with a homoclinic boundary) – one;
HSC (semi-boundary saddle connection) – six;
BSC (boundary saddles connection) – three.

If the boundary is a parabolic cycle:

BPC (boundary parabolic cycle) – two flow.

Except for the case of PC, BDN and BDNH, the structure of the bifurcation is determined by the structure of the flow of codimensionality 1 at the moment of bifurcation. For BDN and BDNH, there are two bifurcations with the formation of a source or a sink. There are infinitely many bifurcation structures for PC if it is a limit cycle of several separatrices on each side, but for the optimal PC flow, the bifurcation is unique.

References

1. Loseva M., Prishlyak A. Topology of Morse-Smale flows with singularities on the boundary of 2-dimensinal disk // Proc. Int. Geom. Center. – 2016. – Vol. 9(2). – P. 32-41. [doi: 10.15673/tmgc.v9i2.279]
2. Prishlyak A., Loseva M. Topology of optimal flows with collective dynamics on closed orientable surfaces // Proc. Int. Geom. Center. – 2020. – Vol. 13(2). – P.50-67. [doi: 10.15673/tmgc.v13i2.1731]
3. Prishlyak A.O., Loseva M.V. Optimal Morse-Smale flows with singularities on the boundary of a surface // J. Math. Sci., New York. – 2019. – Vol. 243(2). – P. 279-286. [doi: 10.1007/s10958-019-04539-9]
4. Lychak D.P., Prishlyak A.O. Morse functions and flows on nonorientable surfaces // Methods Funct. Anal. Topol. – 2009. – Vol. 15(3). – P. 251-258.
5. Prishlyak, A.O., Prus, A.A. Three-Color Graph of the Morse Flow on a Compact Surface with Boundary. J. Math. Sci. – 2020. – Vol. 249(4). – P. 661-672. [doi: 10.1007/s10958-020-04964-1]
6. Prishlyak A., Ivanyuk I. Topology of set of vector fields on surface // Proc. Intern. Geom. Center. – 2013.– Vol.6(4).– P. 44–51.

HYPERPARAMETER TUNING FOR ANT COLONY ALGORITHM WITH RAINFORCMENT LEARNING NEURAL NETWORKS

Lutai A.S.
Taras Shevchenko National University of Kyiv, Ukraine
artemlutay042@gmail.com

The traveling salesman problem is one of the most famous combinatorial optimizations. As it is an NP-complex problem, finding its accurate solution is slow for many cities, but many optimizations can speed up finding a solution close to the best. One of them – Ant colony optimization. This optimization is inspired by the foraging behavior of some ant species. Ants deposit pheromone, which allows other members of the colony to find a favorable path – as more pheromone on the path, the more preferable path is [1].

But implementation of ACO for TSP requires the use of several hyperparameters: two general: ants count, and pheromone evaporation coefficient, and two, that influence path choosing on each step: pheromone and path length influence coefficients. So our task was to find the best approach to find this parameter for each graph, before the start of ACO. For this purpose, we have chosen reinforcement neural networks [2], where reinforcement is based on the difference between the length of the best find path by ACO on the current and previous steps. Input data for the neural network can be derived from our graph – such parameters as barycenter, nodes dispersion, number of nodes, etc. With enough time for training, this could allow us to get a set of hyperparameters for ACO that is close to the best for each graph, so the solution for TSP found by this optimization will also be close to the accurate one.

References

1. Dorigo, M., & Gambardella, L. M. (1997). Ant colony system: a cooperative learning approach to the traveling salesman problem. *IEEE Transactions on evolutionary computation*, *1*(1), 53-66.
2. Sutton, R. S., & Barto, A. G. (2018). *Reinforcement learning: An introduction*. MIT press.

LIMIT LAWS FOR TOTAL PROGENY IN MULTITYPE AGE-DEPENDENT PROCESSES

T.B. Lysetskyi, Ya.I. Yeleyko
Ivan Franko National University of Lviv, Ukraine
Taras.Lysetskyi@lnu.edu.ua

Consider multitype indecomposable age-dependent branching processes ξ and η, where latter denote process with immigration. It is known that in case of constant transition probabilities for the processes ξ, total number of cells born by t (also called total progeny), 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.

We prove those results are true for the case of variable transition probabilities. Also, if we consider decomposable processes, same convergences are valid for the total number of emigrants from main cluster of types.

References

1. T.B.Lysetskyi, Ya. I. Yeleiko. Limit theorems for total number of particles in critical age-dependent branching processes // Precarpathian Bulletin of the Shevchenko Scientific Society. – 2021. – №16(60). – Pp. 33–46 (in ukrainian).

MULTIPLE CRITERIA DECISION MAKING BASED ON SEMI-SUPERVISED PREFERENCE LEARNING

L. Lyubchyk, G. Grinberg, K. Yamkovyi
National Technical University "Kharkiv Polytechnic Institute", Ukraine
Leonid.Liubchyk@khpi.edu.ua

The problem of general performance indicator (GPI) design based on aggregation of a set of partial indexes is considered. An GPI usually understood as a scalar function that in a certain sense defines a generalized quality characteristic of the objects under consideration and depends on a set of partial indexes that characterize their individual features or properties Within semi-supervised learning concept, it is assumed that training dataset consists of a group of objects with measured values of partial indexes and expert assessment of the corresponding values of GPI and a group of objects, for which expert information is not available. This situation is more realistic, since the involvement of experts is associated with certain material costs and the expediency of its limiting is obvious.

For estimation of GPI linear model parameters, the method of optimal concordation of partial indices relative importance weights and GPI expert assessment is used [1]. A nonlinear model is also design on the basis of kernel-based model approach with regularization by optimal concordation with linear model parameters estimates. In accordance with the approach, proposed in [2], linear model parameters estimates are used as *a priori* information for nonlinear problem regularization.

Under semi-supervised learning framework, unlabeled dataset provides additional regularization using the graph data model by smoothing GPI model on data cloud, taking into account the distance between its elements. At that, an unlabelled dataset is used for kernel functions transformation for model smoothing considering data geometric structure [3].

References

1. Lyubchyk L, Grinberg G. Online Ranking Learning on Clusters. – IEEE 2-nd Intern. Conf. on Data Stream Mining & Processing. 2018. – pp.193-197.
2. Lyubchyk L., Galuza A., Grinberg G. Semi-supervised Learning to Rank with Nonlinear Preference Model. – In: Recent Developments in Fuzzy Logic and Fuzzy Sets, vol. 391. Springer, 2019. – pp. 81-103.
3. Lyubchyk L., Grinberg G., Yamkovyi K. Integral Indicator for Complex System Building Based on Semi-Supervised Learning. – 2018

IEEE First International Conference on System Analysis & Intelligent Computing (SAIC), 2018. – pp. 1-5.

ON ESTIMATING THE RATE OF CONVERGENCE OF STATIONARY PROBABILITIES FOR RETRIAL SYSTEM WITH QUEUE

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

A significant part of the queueing theory is the results on of systems with repeated calls (retrial queues). The detailed overviews of the related references with retrial queues can be found in [1] - [3].

In this paper a multiserver retrial queueing system with the finite number of servers, a finite length queue and an infinite orbit is considered. We deal with a Markov model of the system with repeated calls and queue with variable rate of input flow controlled by threshold strategies. At first for such system the existence conditions of stationary regime are pointed out. Further analysis is based on the approximation of the initial systems by the ones with limited orbit for which explicit vector-matrix formulas of stationary probabilities are found. We obtained effective calculating algorithms for the characteristics of the systems in stationary regime in terms of parameters of the systems. For threshold control strategies the optimization problem of the total revenue of the system was stated and solved. The rate of convergence of stationary distribution of finite system involved one server and one place in the queue to this of infinite system under threshold strategies were obtained. A numerical example of solving optimization problem for a stochastic system is given. The program allows determining the optimal strategies for changing the parameters of the system, depending on the specified quality functional. The results of the paper can find application for solving modern practical problems that arise during the creation and operation of mobile communication systems, computer networks, call centers. The program can be applied to solve optimization problems for different adaptive control strategies.

References

1. Falin G.I., Templeton J.G.C. Retrial queues. – London Chapman & Hall, 1997. – 331 p.

2. Artalejo J.R., Gomez-Corral A. Retrial Queueing Systems. – Springer, 2008.
3. Lebedev E., Makushenko I., Livinska H.,Usar I. On Steady-State Analysis of [M|M|m|m+n]-Type Retrial Queueing Systems. - TMM 2017. Communications in Computer and Information Science, vol. 800. Springer, Cham, P. 133-146.

SOLUTION OF CAUCHY PROBLEM OF DISCRETE MULTIPLICATIVE-POVERATIVE-ADDITIVE DERIVATIVE THIRD-ORDER EQUATION

Aygun Malik Mammadzade
Lankaran State University, Azerbaijan
mammadzada.aygun@mail.ru

The article considers the third-order discrete mixed derivative equation for Cauchy problem. By using the definitions of discrete additive derivatives, discrete multiplicative derivatives and discrete poverative derivatives, these derivatives are removed and the general solution of given discrete multiplicative-poverative-additive derivative equation depending on three arbitrary constants is set up and then these arbitrary constants are defined from primary conditions, thus Cauchy problem is solved.

The continuous poverative derivative equation has not yet been determined. Problems for discrete poverative derivative equations can be acquainted in [1] - [5].

Setting of the Problem: Now let's look at the equation:

$$((y_n^{[I]})^{\{I\}})^{(I)} = f_n, \quad n \geq 0. \tag{1}$$

Here $f_n, n \geq 0$ is a given sequence, $y_n, n \geq 0,$ are the sought sequences. Using the definition of a discrete additive derivative, (1) comes to the form as follows: $(y_{n+1}^{[I]})^{\{I\}} - (y_n^{[I]})^{\{I\}} = f_n, \quad n \geq 0.$

Here, assuming to the n, then we get

$$(y_1^{[I]})^{\{I\}} - (y_0^{[I]})^{\{I\}} = f_0,$$
$$(y_2^{[I]})^{\{I\}} - (y_1^{[I]})^{\{I\}} = f_1,$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$(y_n^{[I]})^{\{I\}} - (y_{n-1}^{[I]})^{\{I\}} = f_{n-1}.$$

By summarizing them side by side,

$$(y_n^{[I]})^{\{I\}} = (y_0^{[I]})^{\{I\}} + \sum_{k=0}^{n-1} f_k, \quad n \geq 0. \tag{2}$$

This expression we get. If we accept the marking as follows:

$$(y_0^{[I]})^{\{I\}} + \sum_{k=0}^{n-1} f_k = g_n((y_0^{[I]})^{\{I\}}). \tag{3}$$

Then from (2), we get:

$$(y_n^{[I]})^{\{I\}} = g_n, \quad n \geq 0. \tag{4}$$

With the same rule, by using the definition of a discrete additive derivative, we can note (4) $\sqrt[y_n^{[I]}]{y_{n+1}^{[I]}} = g_n$, or

$$y_{n+1}^{[I]} = g_n^{\,y_n^{[I]}}, \quad n \geq 0 \tag{5}$$

in this form. Here we get from (5) by giving values to n:

$$y_1^{[I]} = g_0^{\,y_0^{[I]}}, \quad y_2^{[I]} = g_1^{\,y_1^{[I]}} = g_1^{\,g_0^{\,y_0^{[I]}}}, \ \ldots \ y_n^{[I]} = g_{n-1}^{\,g_{n-2}^{\,\iddots^{\,g_0^{\,y_0^{[I]}}}}}, \tag{6}$$

If we accept the marking as follows:

$$y_n^{[I]} = g_{n-1}^{\,g_{n-2}^{\,\iddots^{\,g_0^{\,y_0^{[I]}}}}} = h_n(y_0^{[I]}). \tag{7}$$

Then we get from (6):

$$y_n^{[I]} = h_n, \quad n \geq 1. \tag{8}$$

Finally, using the definition of a discrete multiplicative derivative, we obtain from (8):

$$\frac{y_{n+1}}{y_n} = h_n, \quad n \geq 1. \tag{9}$$

Here, by giving values to n,

$$\frac{y_2}{y_1} = h_1, \quad \frac{y_3}{y_2} = h_2, \ldots \quad \frac{y_n}{y_{n-1}} = h_{n-1}.$$

If we multiply the obtained expressions side by side:

$$y_n = y_1 \cdot \prod_{s=1}^{n-1} h_s. \tag{10}$$

Then we get this expression.

Cauchy problem: In view that the given equation (1) is third-order, let us give the following initial conditions for this equation

$$y_k = \alpha_k, k = \overline{0,2}, \tag{11}$$

then, from (3) :

$$g_n((y_0^{[I]})^{\{I\}}) = \sqrt[\frac{\alpha_1}{\alpha_0}]{\frac{\alpha_2}{\alpha_1}} + \sum_{k=0}^{n-1} f_k. \tag{12}$$

But from (7) we get follows

$$h_n(y_0^{[I]}) = g_{n-1}^{g_{n-2}^{\cdot^{\cdot^{\cdot^{g_0^{\frac{\alpha_1}{\alpha_0}}}}}}}, \qquad (13)$$

Because in (1), (11) solution of Cauchy problem, so we get the following solution:

$$y_n = \alpha_1 \cdot \prod_{s=1}^{n-1} h_s. \qquad (14)$$

Theorem 1. If $f_n, n \geq 0$ is given sequence, α_0, α_1 and α_2 are given positive constatnts, then (1), (11) there is only one solution of Cauchy problem and this solution is giving via (12)-(14).

References

1. Aliyev N.A., İbrahimov N.S., Mammadzada A.M. On a solution of the Cauchy problem for the discrete equation with powerative-multiplicative-additive derivatives // XXXI İnternational Conference Problems of Decision Making under Uncertainties (PDMU-2018). Abstracts. Lankaran, Republic of Azerbaijan, 03-07 July,2018.–P.16-17.
2. Mammadzada A.M., Aliyev N.A., İbrahimov N.S. Solution of Cauchy problem for third discrete derivative additive-multiplicativo-poverativo derivative equation// XXXII International Conference Problems of Decision Making Under Uncertainties (PDMU-2018), Abstracts, Czech Republic, Pragua, 24 Augast - 01 September 2018. – P. 84-86.
3. Aliyev N.A., İbrahimov N.S., Mammadzada A.M. Solution of Cauchy and boundary problems for the third compilation discrete additive-multiplicative-powerative derivative equation // Вісник Київського Національного Університету імені Тараса Шевченка, Серія Фізико -Математичні Науки. – 2018. – №1. – С. 50-54.
4. Aliyev N.A., İbrahimov N.S., Mammadzada A.M. Solution of Couchy problem for a discrete powerative // XXXV İnternational Conference Problems of Decision Making Under Uncertainties (PDMU-2020) ABSTRACTS. – Baku-Sheki, 11-15 May, 2020. –P. 13-15.
5. Mammadzade, A.M. Solution of Couchy and boundary value problems for a discrete powerative derivative cubic equation // Воронежский государственный университет, Вестник ВГУ. серия: Физика. Математика. – 2020. – № 1. – P. 24-30.

COMPETENCY-BASED CHALLENGES OF APPLIED ARTIFICIAL INTELLIGENCE: PROJECT FAAI

Vasyl Martsenyuk[1], Georgi Dimitrov[2], Dejan Rancic[3], Iveta Dirgová Luptáková[4], Savo Tomovic[5], Marcin Bernas[1], Aleksandra Klos-Witkowska[1], Tomasz Gancarczyk[1], Andrii Sversiuk[6], Igor Andrushchak[7]

[1]University of Bielsko-Biala, Poland
[2]University of Library Study and Information Technologies, Bulgaria
[3]University of Nis, Serbia
[4]University of Ss Cyril and Methodius in Trnava, Slovakia
[5]University of Montenegro, Montenegro
[6]TNMU, Ukraine
[7]Lutsk National Technical University, Ukraine

The usage of ICT has improved effectiveness and efficiency, led to significant savings, and change in daily life, this, in turn, has led to the need for more intelligent use of available resources, which in turn leads to environmental protection. European countries have recognized the importance of ICT for society and all business processes.

Applied Artificial Intelligence addresses concerns in applied research and applications of artificial intelligence (AI). The work is fulfilled in the framework of Erasmus+ project 2022-1-PL01-KA220-HED-000088359 “The Future is in Applied Artificial Intelligence” (FAAI). The project aims to join together HEIs, businesses in order to address the competencies and compatible job profiles. This collaboration will provide innovative solutions for the training of ICT specialists in the field of artificial intelligence. The learning framework is based on IEEE guidelines for Machine Learning.

The main goal is for students to get acquainted with the possibilities of AI systems for solving problems in management, industry, engineering, administration, and education; evaluations of existing AI systems and tools, emphasizing comparative studies and user experiences; and the economic, social, and cultural impacts of AI.

The project’s main ideas are:

- Developing joint university training program in the field of applied artificial intelligence with same or similar curricula for MSc degree
- Use of appropriate, competence-based flexible forms of training, supported with MOOC

- Developing virtual laboratory for students, researchers, and experts
- Creating a sustainable relationship with business organizations in need of experts in the field of artificial intelligence
- Sharing and working on real problems

The expected project results are

- Establishment of the long-term strategic partnership and cooperation in education, research, business, and innovation.
- Train the educators and experts in the field of the practical application of the possibilities of artificial intelligence
- Increased regional public awareness of the opportunities offered by the use of new technologies

References

1. Martsenyuk V., Klos-Witkowska A., Sverstiuk A., Bahrii-Zaiats O., Bernas M., Witos K. Intelligent big data system based on scientific machine learning of cyber-physical systems of medical and biological processes (2021) CEUR Workshop Proceedings, 2864, pp. 34 – 48
2. Nakonechnyi O., Martsenyuk V., Klos-Witkowska A., Zhehestovska D. Minimax Combined with Machine Learning to Cope with Uncertainties in Medical Application, Lecture Notes in Networks and Systems, Volume 217, Pages 713 – 720, 2022 6th International Congress on Information and Communication Technology, ICICT 2021 DOI: 10.1007/978-981-16-2102-4_64

ON MINIMUMS OF FUZZY NUMBERS WITH FUZZY SETS OF OPERANDS

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

Assume that fuzzy numbers (FNs) f_j, $j \in N$ with the corresponding membership functions (MFs) $\varphi_j(x_j)$ are defined on the real line $\mathbb{R}$, where $N = \{1,2,...,n\}$ is the index set and n is the cardinality of the set N. Let $\tilde{N}$ be a fuzzy set on the set N of operand indices with the arbitrary MF $\eta(j)$, $j \in N$. This paper develops researches [1,2] about operations on fuzzy numbers with a fuzzy set of operands. We propose the minimum of fuzzy numbers f_j, $j \in N$ with the fuzzy set $\tilde{N}$ of

operands. We demonstrate that the resulting set is a type-2 fuzzy set (T2FS). The type-2 MF of this set is constructed. The minimum T2FS can be decomposed according to secondary membership grades into the corresponding collection of FNs. It helps to represent the minimum operation on FNs with a fuzzy set of operands in a form which is convenient for a proper understanding and applications. In this report we intend to discuss different applications of this operation.

There are many real-life situations (ranging from global problems to everyday ones) in which there is a need to calculate such minimums. For instance, let f_j be a FN that expresses an expert estimate of the greenhouse gas emission of the country $i \in N$, where $N = \{1,2,...,n\}$ is the set of countries, n is the cardinality of N. Assume that $\tilde{N} = \{(i;\eta(i)) : i \in N\}$ is a fuzzy set of 'rich' countries with MF $\eta(i)$, $i \in N$. Then one may ask what is the minimum greenhouse gas emission of 'rich' countries? This is an example of the minimum of FNs f_j, $i \in N$ with the fuzzy set ('rich' countries) $\tilde{N} = \{(i;\eta(i)) : i \in N\}$ of operands.

References

1. MASHCHENKO, S. (2018) Sums of fuzzy set of summands. *Fuzzy Sets Syst.*, 417, p. 140–151.

2. MASHCHENKO, S. (2021) Sum of discrete fuzzy numbers with fuzzy set of summands. *Cybernetics and Systems Analysis*, 57(3), p. 374–382.

COMMON SOLUTION OF THE TERMINAL CONTROL PROBLEM FOR A LINEAR DISCRETE SYSTEM

V. Matvienko, V. Pichkur, Ya. Trotsenko, D. Cherniy
Taras Shevchenko National University of Kyiv, Ukraine
matvienko.vt@gmail.com, volodymyr.pichkur@knu.ua, yaroslav.p.trotsenko@gmail.com, d_cherniy@ukr.net

The problem of terminal control is one of the basic ones in control theory. For a linear control system, the solvability conditions of such a problem are related to controllability criteria. At the same time, the problem of constructing a set of all controls that would provide a solution to the terminal control problem arises. The parametric representation of the entire class of such controls will be considered a

general solution. At the same time, if the controllability conditions for the control system are not fulfilled, then the task is to find the controls that would ensure the transition to the closest state to the given one and, accordingly, to find all such controls in a parametric form. Such problems have a significant applied value, in particular, in the tasks of analyzing the functional stability of technological processes [1-3]

The report proposes the construction of a general solution to the problem of terminal control of a linear discrete system. Necessary and sufficient conditions of existence, conditions of unity, solution of the terminal control problem, definition of the general solution of the terminal control problem of a linear discrete system are given. A general solution of the terminal control problem for a linear system is constructed. A general pseudo-solution for a linear system under the condition of loss of controllability in the final state is found. In addition, a solution to the problem of constructing the reachability set from the origin of the coordinates with restrictions on the norm of the control function was obtained. Numerical results of solving the problem of terminal control of a discrete oscillating system of two masses are given.

Reference

1. Kirichenko, N.F., Matvienko, V.T. Optimal synthesis of structures for linear control systems. // J. of Automation and Information Sciences. – 1998. – 30(1). – P. 18-28.

2. Кириченко Н.Ф., Лепеха Н.П. Псевдообращение в задачах управления и наблюдения.// Автоматика. – 1993. – №5. – С.69-81.

3. Pichkur V.V., Sobchuk V.V. Mathematical Model and Control Design of a Functionally Stable Technological Process // J. of Optimization, Diff. Equations and their Applications.– 2021. – 29(1). – P.32-41.

THE IMPORTANCE OF A NEW SPECIALTY WITH APPLIED MATHEMATICS

F.E. Mirzayev, R.M.Guliyev, Z.Y. Shabiyeva

Baku State University, Azerbaijan

Farhad_1958@mail.ru, shabiyeva.zuleyxa@gmail.com

It is known that in the modern era, the solution of tasks such as the preparation and adoption of effective management decisions that ensure the optimal management of the economy and its separate important areas requires the use of the latest achievements of higher mathematics, mathematical-statistical methods and computational techniques in

economic-mathematical research. This necessity has led to the creation of a new scientific direction - actuarial and financial mathematics - which has emerged in modern times as a general result of the unity of applied mathematics, statistics, economics and computer science.

"Actuarial and financial mathematics" exists as a speciality with applied importance in the universities of many developed countries. "Actuarial and financial mathematics" is a field of science formed based on the scientific direction of economic cybernetics, like econometrics. Specialists trained in this direction are considered the most desirable specialists of insurance companies and banks, having earned the qualification "insurance and financial mathematician".

It should also be noted that from 1991 to 2009, at the Faculty of Applied Mathematics and Cybernetics of BSU, staff training was carried out at the undergraduate level in the speciality "Economic Cybernetics", and the passing score for this speciality was very high every year compared to other specialities. BSU graduates who have acquired this qualification are working effectively in several leading state bodies, well-known companies, and scientific research institutions of Azerbaijan today.

At the moment, "Actuarial mathematics" and "Financial mathematics" subjects are successfully taught as elective subjects at the undergraduate level at the Faculty of Applied Mathematics and Cybernetics of BSU. For a long time, the subjects "Fundamentals of Actuarial Mathematics" and "Fundamentals of Stochastic Financial Mathematics" have been taught at the master's level of the "Operations Research and Probability Theory" department. Also, a new master's degree called "Actuarial Mathematics" was opened under the "Economic Cybernetics" department. We believe that opening a suitable bachelor's degree in this field is the need of nowadays.

Currently, the scientific and pedagogical potential of the Faculty of Applied Mathematics and Cybernetics of BSU (Economic Cybernetics, Mathematical Cybernetics, Operations Research and Probability Theory, Optimization and Management, Information Technologies and Programming, Applied Mathematics, Mathematical Methods of Applied Analysis, Informatics, Mathematical Physics Equations Departments) - the pedagogical potential is intended) and in recent years, the cooperation of the faculty with the world's leading scientific centres allows the creation of the speciality "Actuarial and financial mathematics" and personnel training in this field. Worth noting that specialist training in this direction is conducted at several universities

around the world. Students educated in this speciality will have the skills to evaluate and analyze data collected as a result of the educational process, apply probabilistic-statistical methods to assess insurance and financial risks, and predict the price of various financial instruments using mathematical methods.

Students who graduate from "Actuarial and financial mathematics" will be able to work as "actuarial-mathematicians" in insurance companies and "financier-mathematicians" in the banking sphere.

Letters to Baku State University from the country's leading financial, banking, insurance, and social protection institutions that need specialists in this speciality show that it is important to open this speciality at the bachelor's level of education.

Taking into account the above, as well as the existing material and technical base of the BSU, the Faculty of Applied Mathematics and Cybernetics has sufficient staff potential, the "Actuarial and Financial Mathematics" speciality will be "Bachelor of Higher Education (main We consider it appropriate to add the "Classification of specializations (programs) at the base higher) medical education) level to the group of natural specialities and we hope that the university branches located in the regions support this justified proposal of Baku State University and apply to the necessary institutions with this proposal, which is important in meeting the market demand. they will have done work. Indeed, one of the most important issues facing our education today is the restoration or reopening of qualifications that are needed in the market.

As we know, application of applied mathematics mathematical methods in various fields, including physics, engineering, medicine, biology, business, computer science, industrial engineering, economy, finance is an important issue of the day. Thus, we can confidently say that applied mathematics is a combination of mathematical science and specialized knowledge. The term applied mathematics also describes a professional specialty in which mathematicians work on practical problems by formulating and studying mathematical models.

The new actuarial and financial mathematics specialty we are talking about today is the demand of today and the dictates of labor market.

INFLUENCE FACTORS OF DECISION-MAKING SYSTEMS ON ENTERPRISE MANAGEMENT

V. Kh. Muradova
Lankaran State University, Azerbaijan
viusalia.muradova@nure.ua

Whether in our daily life or in large enterprises and corporations, people often face decision-making situations. Some of the decisions we make are intuitive, while others automatically follow a repetitive decision-making process. Currently, the rapid development of the market economy, in a period of strong competition, creates great difficulties for managers and responsible persons in making decisions about the development of the enterprise and the situation at that moment. This decision usually cannot be made immediately. At this time, it is necessary to have a large number of alternatives, based on which the positive and negative sides of the decision are analyzed, and a comprehensive evaluation of the choice is carried out. Decision-making by a single person often does not produce positive results. Usually, therefore, decision-making is carried out according to the consultation of experienced persons. The decision made here is very important. Because the right decision leads the enterprise to development, and the wrong decision leads to failure. Such situations are common in management. Decision-making systems are applied in every field of enterprises. The main factors that make decision-making an integral part of management are the following: decision-making is carried out at all stages of management; decision-making is the most important part of any business leader's activity; the modern model of economic systems is decision-making systems. One of the other important factors of decision-making systems for the enterprise is that it has a great role and place in improving the quality of management processes, for example, providing the manager with complete information, taking into account background data, obtaining a quick optimal decision, saving time, and a number of characteristic features such as analysis of the moment, reduction of financial costs can be shown.

References

1. Aliyev Rafiq, Aliyev Rashad. "Soft Computing". – Baku, 2003.
2. Zade L.A. The concept of a linguistic variable and its application to the adoption of approximate decisions. – M.: Mir, 1976.

GUARANTED ROOM MEAN SQUARE ESTIMATES OF VECTORS AND THEIR ERRORS IN OBSERVATION PROBLEMS WITH UNCERTAINTIES

O.G. Nakonechnyi, G.I. Kudin, P.M. Zinko, T.P. Zinko
Taras Shevchenko National University of Kyiv, Ukraine
a.nakonechnyi@gmail.com

Let the following scalar values be observed:

$$y_k = sp(XA_k^T) + \eta_k, \quad k = \overline{1,N}\ , \tag{1}$$

where $X \in H_{m\times n}$ - is an unknown matrix, solution of the linear equation:

$$AX = BF\ , \tag{2}$$

$A \in H_{m\times m}$ $(\det A \neq 0)$, $B \in H_{m\times m}$ – are known matrices; $F \in H_{m\times n}$ – is an unknown matrix belonging to some finite set $\breve{G}$; $A_k \in H_{m\times n}$, $k = \overline{1,N}$ – known matrices; $H_{m\times n}$ – space of matrices with dimensions $m\times n$; $sp(W)$ – square matrix trace W; $sp(XA_k^T) = \langle X, A_k \rangle$ – matrix scalar multiplication; T – symbol for transposing matrices; η_k, $k \in \overline{1,N}$ – sequence of random variables.

Let's introduce a linear operator $\wp$, which operates from a vector space R^N into a matrix space $H_{m\times n}$ and a linear operator $\wp^*$, conjugated to the operator $\wp$:

$$\wp x \equiv \sum_{k=1}^{N} A_k x_k = X; \quad \wp^* X \equiv (sp(X^T A_1),...,sp(X^T A_N))^T;$$

as well as vectors $y = (y_1,...,y_N)^T$, $\eta = (\eta_1,...,\eta_N)^T$. Observation (1) has the following vector form $y = \wp^* X + \eta$.

We assume that the average value of the random vector $\eta \in R^N$ – is a zeroed vector, meaning $E\eta = 0$ (E – expected value symbol), but a correlation matrix $R = E\eta\eta^T$ is unknown and belongs to bounded sets G_2 or G_3 $G_2 = \{R : sp(R - R_0)^2 \le q^2\}$, $G_3 = \{R : sp(Q_2 R) \le q^2\}$, where $R_0 = (r_{kj}^{(0)})_{k,j=\overline{1,N}}$ – is a known symmetric negatively-defined matrix, q^2 – is a known positive real number, $Q_2 \in H_{N\times N}$ – is a known symmetric positively-defined matrix.

Introducing a linear operator L, that operates from space $H_{m\times n}$ into

space R^s $L\,X = (\langle V_1, X\rangle, ..., \langle V_s, X\rangle)^T$, where $V_i \in H_{m\times n}$, $i \in \overline{1,s}$ – are known matrices.

Definition 1. A linear estimate of element $L\,X$ is called an element $\hat{LX}$ possessing the following form:

$$\hat{LX} = Uy + c \equiv \sum_{k=1}^{N} u^k y_k + c,$$

where $u^k \in R^s$, $k = \overline{1,N}$, $U -$ is a linear operator, which reflects vector space R^N into a space R^s, vector $c \in R^s$.

Definition 2. Guaranteed root mean square error estimates $\hat{LX}$ are such values where

$$\sigma_i\,(U,c) = \{\max_{G,G_i} E \left\| \hat{LX} - L\,X \right\|^2 \}^{\frac{1}{2}}, \quad i = 2,3,$$

$$\left\| \hat{LX} - L\,X \right\|^2 = sp((\hat{LX} - L\,X)(\hat{LX} - L\,X)^T).$$

Definition 3. Estimates $\bar{LX} = \bar{U}^{(i)} y + \bar{c}^{(i)}, i = 2,3$, for which values $\left(\bar{U}^{(i)}, \bar{c}^{(i)}\right)$, $i = 2,3$ are calculated from these conditions

$$\left(\bar{U}^{(i)}, \bar{c}^{(i)}\right) \in Arg \min_{U,\,c} \sigma_i(U,c), \quad i = 2,3$$

are called guaranteed root meat square error estimations.

Let's introduce vectors $u_{(p)} = \left(u_p^1, u_p^2, ..., u_p^N\right)^T$, $p = \overline{1,s}$, where u_p^k, $k \in \overline{1,N} -$ p-th vector component u^k.

Claim 1. Let $X \in H_{m\times n} -$ be an unknown matrix which satisfies equation (2), while for a random vector η ($E\eta = 0$) unknown correlation matrix $R = E\eta\eta^T$ belongs to the sets G_2 or G_3. Then, for $i = 2$ or $i = 3$ and $c = 0$ for vector estimates

$$\hat{LX} = (U^{(i)}, y) = ((u_{(1)}^{(i)}, y), ..., (u_{(s)}^{(i)}, y))^T, \quad i = 2,3$$

the following equality holds:

$$\max_{G,G_i} E \left\| \hat{LX} - L\,X \right\|^2 = J_1(U^{(i)}) + J_i(U^{(i)}), \quad i = 2,3,$$

where $J_1(\mathbb{U}^{(i)}) = \max\limits_{F \in \bar{G}} \sum\limits_{p=1}^{s} sp(B^T Z_p^{(i)} F^T)$,

$$J_2(U^{(2)}) = \sum_{p=1}^{s} (R_1^{(0)} u_{(p)}^{(2)}, u_{(p)}^{(2)}) + |q| \{ \sum_{p,j=1}^{s} (u_{(p)}^{(2)}, u_{(j)}^{(2)})^2 \}^{1/2},$$

$$J_3(U^{(3)}) = q^2 \sum_{p=1}^{s} \lambda_{\max}\ (D),\ D = (Q_2^{-1} u_{(p)}^{(3)}, u_{(j)}^{(3)})_{p,j=\overline{1,s.}},$$

and matrices $Z_p^{(i)}$ – are solutions to equations:

$$A^T Z_p^{(i)} = V_p - \rho u_{(p)}^{(i)},\ i = 2,3, \quad p = \overline{1,s.}$$

The paper examines problems of linear estimation of unknown rectangular matrices, which are solutions of linear matrix equations, the right-hand parts of which belong to bounded sets. The random errors of the vector of observations has got zero expected values, and the correlation matrix is unknown and belongs to one of two bounded sets. Explicit expressions of the guaranteed root-mean-square errors of estimates of linear operators acting from the space of rectangular matrices into some vector space are given. We obtain the guaranteed quasi-minimax root-mean-square errors of linear estimates. As test examples, two options for solving the problem are considered, taking into account small disturbances of known observation matrices.

References

1. Sourav Chatterjee, Matrix Estimation by Universal Singular Value Thresholding // The Annals of Statistics. – 2015. – Vol. 43, No. 1. – P. 177 – 214.

2. Negahban S., Wainwright M. J. (2011). Estimation of (near) low-rank matrices with noise and high-dimensional scaling // Ann. Statist. – 2011. – Vol. 39. – P. 1069–1097.

3. Наконечний А.Г., Кудин Г.І., Зинько П.Н., Зинько Т.П. Метод збурювань у задачах лінійної матричної регресії //Проблеми керування й інформатики. – 2020. – №1. – С. 38-47.

4. Наконечний О.Г., Кудін Г.І., Зінько П.М., Зінько Т.П. Наближені гарантовані оцінки матриць у задачах лінійної регресії з малим параметром // Системні дослідження та інформаційні технології. - 2020. – № 4. – С. 88–102.

5. Наконечний А.Г., Кудин Г.І., Зинько П.Н., Зинько Т.П. Гарантовані середньоквадратичні оцінки лінійних перетворень матриць в умовах статистичної невизначеності // Проблеми керування й інформатики. – 2021. – №2. – С. 24-37.

ON A PROBLEM FOR THE HYPERBOLIC TYPE EQUATION WITH NON-LOCAL AND GLOBAL CONDITIONS

Shabina Niftullayeva
Lankaran State University, Azerbaijan
Sebineniftullayeva_90@mail.ru

We consider the following boundary value problem

$$\frac{\partial u(x)}{\partial x_2}+\frac{\partial u(x)}{\partial x_1}=0,\ x=(x_1,x_2)\in D_s\subset R^2, \tag{1}$$

$$\alpha_1(x_1)u_1(x_1,0)+\alpha_2(x_1)u\big(x_1,\gamma(x_1)\big)+$$
$$+\int_{a_1}^{b_1}K_1(x_1,t)u(t,0)dt+\int_{a_1}^{b_1}K_2(x_1,t)u(t,\gamma(t))dt+$$
$$+\int_{D_2}K(x_1,\xi)u(\xi)d\xi=\alpha(x_1),\ \ x_1\in[a_1,b_1]. \tag{2}$$

Here D is a bounded convex on the direction x_2 plane domain; the boundary $\Gamma=\partial D$ is piece-wise Lyapunov line; $\alpha_k(x_1),k=1,2;$ $K_j(x_1,t),\ j=1,2;$ $K(x_1,\xi)$ and $\alpha(x_1)$ are given continuous functions; $x_2=\gamma(x_1)$ is equation of upper boundary of D; ν is outward normal to D.

It is known that the fundamental solution to (1) in the direction x_2 is in the form

$$U(x-\xi)=e(x_2-\xi_2)\delta\big(x_1-\xi_1-(x_2-\xi_2)\big). \tag{3}$$

Here $e(t)$ is Heaviside's symmetric unit function, $\delta(t)$ is Dirac function.

The main relation for (1) is obtained using fundamental solution (3) by the help of Gauss-Ostrogradsky formula as follows

$$0=\int_D\frac{\partial u(x)}{\partial x_2}U(x-\xi)dx+\int_D\frac{\partial u(x)}{\partial x_1}U(x-\xi)dx=\int_{\partial D}u(x)U(x-\xi)\times$$
$$\times\big[\cos(\nu,x_2)+\cos(\nu,x_1)\big]dx-\int_D u(x)\left[\frac{\partial U(x-\xi)}{\partial x_2}+\frac{\partial U(x-\xi)}{\partial x_1}\right]dx,$$

or

$$-\int_{a_1}^{b_1}u(x_1,0)U(x_1-\xi_1,-\xi_2)dx_1+\int_{a_1}^{b_1}u\big(x_1,\gamma(x_1)\big)U\big(x_1-\xi_1,\gamma(x_1)-\xi_2\big)\times$$

$$\times\left[\cos(\nu,x_2)+\cos(\nu,x_1)\right]\frac{dx_1}{\cos(\nu,x_2)}=\begin{cases}u(\xi), & \xi\in D,\\ \frac{1}{2}u(\xi), & \xi\in\partial D.\end{cases} \quad (4)$$

The first term of (4) is an arbitrary solution of (1) in D and the second term is the necessary condition related to the boundary.

After regularization these necessary conditions together with condition (2) form the sufficient conditions for the Fredholm property of problem (1)-(2).

CRITERION FOR THE BASICITY OF SYSTEM OF EXPONENTS WITH A LINEAR PHASE IN GRAND-SOBOLEV SPACES

S. A. Nurieva
Azerbaijan Tourism and Management University, Azerbaijan
sada.nuriyeva@inbox.ru

Let $1<p<\infty$. A space $L^{p)}(a,b)$ of measurable functions satisfying the condition

$$f_{p)}=sup_{0<\varepsilon<p-1}\left(\frac{\varepsilon}{b-a}\int_a^b|f|^{p-\varepsilon}\,dt\right)^{\frac{1}{p-\varepsilon}}<\infty$$

in the interval $(a,b)\subset \mathrm{R}$ is called a grand-Lebesgue space.

The space

$$W_{p)}^{\ 1}(a,b)=\left\{f|f,f'\epsilon L^{p)}(a,b),f_{p)}+f'_{p)}<\infty\right\}$$

is called a grand-Sobolev space.

$W_{p)}^{\ 1}(a,b)$ is not a separable space. Denote by $\tilde{M}W_{p)}^{\ 1}(a,b)$ the set of all functions which satisfy the condition $\hat{f}^{'}(\cdot+\delta)-\hat{f}^{'}(\delta)_{p)}\to 0$ as $\delta\to 0$ and belong to $W_{p)}^{\ 1}(a,b)$. Denote by $MW_{p)}^{\ 1}(a,b)$ the closure of $\tilde{M}W_{p)}^{\ 1}(a,b)$ with respect to the norm of $W_{p)}^{\ 1}(a,b)$.

T**heorem.** Let $-2Re\alpha+\frac{1}{p}\notin Z, 1<p<\infty$. Then the system

$$1\cup t\cup\left\{e^{i(n+\alpha signn)t}\right\}_{n\neq 0}$$

forms a basis for the space $MW_{p)}^{1}(-\pi,\pi), 1<p<\infty$, if and only if $\left[-2Re\alpha+\frac{1}{p}\right]=0$.

THE AUTOMATED SYSTEM OF THE VACCINATED PEOPLE`S CONTROLLED ACCESS BASED ON COVID CERTIFICATES

T. Oryshchak, A. Melnychyn
Ivan Franko National University of Lviv, Ukraine
oryshchaktaras@gmail.com, andiy.melnychyn@lnu.edu.ua

One of the global problems of today has become the pandemic of the Covid-19 coronavirus. Among the measures, which are designed to return the world to normal life, is the controlled access to public places only for those who have been vaccinated. For this, it is necessary to organize a check of the presence and originality of the certificate and its belonging to the person presenting this certificate. The traditional organization of such control requires human and economic resources, which is an additional burden for business in crisis conditions. Therefore, an urgent task is to develop an automated system of controlled access of vaccinated persons.

The purpose of the study is to develop an automated system of controlled access to public places based on the validation of the Covid-certificate and verification of the ownership of this certificate to the person displaying it.

To achieve the goal, the following tasks were solved:

- analysis of the subject area;
- system design;
- development of algorithms:
    - o validation of the Covid-certificate based on open data;
    - o identification of the person presenting the certificate;
    - o checking whether the certificate belongs to the person presenting it;
- software implementation of developed algorithms;
- creation of a prototype of an automated system.

Initially, I wanted to develop a system for reading certificates from the action program, but since this program is relatively new, I faced the problem of reading the qr-code and further accessing the electronic

certificate, since they are updated every time and there was a ban on access to the electronic versions of the certificate, but this problem is already a solution. Also, having this knowledge, I developed a system of electronic passes in the form of a qr code.

A system of electronic control using QR codes of passes has been developed.In the future, I plan to improve the security of reading certificates and their verification methods. I plan to add not only certificates but also electronic passports.

INTELLIGENT METHODS FOR ANALYZING AND PROGNOSTICATION OF TELECOMMUNICATION NETWORK TRAFFIC

A. Pashko
Taras Shevchenko National University of Kyiv, Ukraine
aap2011@ukr.net

The paper explores the possibility of using artificial neural networks and autoregressive analysis to build predictive mathematical models of data channel congestion.

The algorithm of construction of autoregressive model on the basis of the statistical analysis of a time series of observations and calculation of fractal dimension of a time series of intensity of traffic is developed. The work continues with research [1-2].

The results are used to prevent DoS attacks. DoS-attacks target both networks as a whole, and the end hosts. The purpose of the attacks is the maximum consumption of resources in order to significantly degrade or stop providing services to users. Usually attacked resources are channel width, CPU time of servers and routers and specific protocol implementations.

The fundamental prerequisite for attack detection is the construction of traffic control characteristics during normal network operation followed by the search for anomalies in the traffic structure, deviation from the control characteristics.

A network traffic anomaly is a network event characterized by a statistical deviation from the standard traffic pattern.

The main way to detect DoS - attack is to detect anomalies in the traffic structure.

Any difference in traffic structure that exceeds a certain threshold value triggers an alarm.

References
1. Pashko, A., Rozora, I. Estimation of the Probability of Buffer Overflow for Self-Similar Traffic.2021 IEEE 8th International Conference on Problems of Infocommunications, Science and Technology, PIC S and T 2021. Proceedings, 2021, стр. 28–32.
2. Pashko, A., Rozora, I., Syniavska, O. Estimation of Hurst Index and Traffic Simulation / Advances in Computer Science for Engineering and Education IV (Lecture Notes on Data Engineering and Communications Technologies), 2021, 83, стр. 37–46.

TWO APPROACHES FOR EVALUATION OF OPTION PRICES UNDER ILLIQUIDITY

V. Pauk, O. Petrenko, N. Shchestyuk
National University "Kyiv-Mohyla Academy", Ukraine
n.shchestiuk@ukma.edu.ua

Analysis of different financial markets shows that during global crises that have a negative impact on financial activity we can observe some kinds of risky assets which have the periods in their dynamic without change. Such behavior is typical for emerging markets with low number of transactions, for interest rate markets and for commodity markets. So, for these markets the problem of evaluating fair price of derivative instruments on stocks has become extremely important.

The classical diffusion models for continuous time like Black-Scholes-Merton and its discrete variant - binomial tree model of Cox-Ross-Rubinstein are incapable of adequately modelling illiquidity for real-life asset dynamic and evaluate derivatives.

In order to overcome this difficulty for discrete-time approach was considered the trinomial tree model. This model improves upon the binomial model by allowing a stock price not only to move up or down, but stay the same with certain probabilities, what are desirable properties for the illiquid modelling.

For continuous-time approach one can notice, that the constant periods of stagnation in financial processes are analogous in nature to the trapping events of the subdiffusive particle. Therefore, the physical models of subdiffusion can be successfully applied to describe financial data. Many types of subordinators such as α-stable, tempered-stable, Gamma, Poisson and other have been already applied for different subdiffusive models of illiquidity.

In this paper we propose to take the Inverse Gaussian process IG as a subordinator for the subdiffusive modelling. The simulation of the trajectories for subordinator, inverse subordinator and subdiffusive GBM were performed. The Monte Carlo method for option evaluation was applied.

Our aim was not only to compare these two models each with other, but also to show that both models adequately describe the illiquid market and can be used for option pricing on this market. For this purpose, absolute relative percentage and root mean squared error for both models were computed and analysed.

Thanks to the proposed approaches, the investor gets the tools, which allows him to take into account the illiquidity.

References

1. Donatien, H., Leonenko, N. N. (2020). Option pricing in illiquid markets: A fractional jump–diffusion approach, *Journal of Computational and Applied Mathematics*, 381.

2. Magdziarz, M. (2009). Black–Scholes formula in subdiffusive regime, *J. Stat. Phys*., 136, 553–564.

3. Wylomanska, A., Kumar, A., Polocz´anski, R., Vellaisamy, P. (2016). Inverse Gaussian and its inverse process as the subordinators of fractional Brownian motion. *Physcal Review*, 96.

4. Shchestyuk, N., Tyshchenko, S. (2021). Monte-Carlo method for option pricing in sub-diffusive arithmetic models. *Bulletin of Taras Shevchenko National University of Kyiv. Series: Physics and Mathematics*, 2, 85-95.

EXISTENCE AND NONEXISTENCE OF GLOBAL SOLUTIONS FOR NONLINEAR PARABOLIC EQUATIONS

R.A. Rasulov

Sheki Branch Azeribajian Pedaqogical University, Azerbaijan

rasulovrafiq@yahoo.com

Let be a bounded domain in *Rn* with smooth boundary , *p* a real number p>2 and *a* a nonnegative real number. In this paper we consider the initial-boundary value problems for nonlinear parabolic equations.

In a recent work , Fujita gave existence and nonexistence theorems for global solutions of the heat equation .

In this paper our purpose is to obtain analogous results for the nonlinear problem

1) in some conditions the problem for p and initial functions,problem has global (nonnegative) solutions belong to some Sobolev space.

2) in some conditions for sufficiently small (nonnegative) initial function the problem has a global (nonnegative) solution. If initial function is nonnegative and large enough, the solution blows up in a finite time.

NUMERICAL SOLUTION OF THE ISENTROPIC AND ADIABATIC EULER SYSTEM FOR POLITICAL GASES IN A CLASS OF DISCONTINUOUS FUNCTIONS

R.A. Rasulov[1], B. Sinsoysal[2]

[1]Sheki branch of Azerbaijan State Pedagogical University, Azerbaijan

[2]Istanbul Gedik University, Faculty of Engineering, Department of Computer Engineering, Istanbul, Turkey

rafiq.rasulov58@gmail.com; bahaddin.sinsoysal@gedik.edu.tr

We consider the following Cauchy problem for 2D Euler`s system of equations

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x},\ \frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial y},$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0.$$

The basic feature of the system of equations is that their solutions have jumps of unknown locations. These features present significant difficulties in implementing the classical methods to find the solution of the equation during their own time. For this goal a special auxiliary problem is suggested having some advantages over the main problem as follows

$$\frac{\partial \Phi^*}{\partial t}+\frac{1}{2}U^2+\frac{p}{\rho}=0,\ \text{ where }\ \Phi=\Phi^*+\int_0^t c(\tau)d\tau$$

The auxiliary problem permits us to construct an efficient numerical algorithm [1-2].

References

1. Abasov M.T., Rasulov M.A., Ragimova A.T. Identification of the saturation jump in the process of oil displacement by water in a two-dimensional domain // Soviet Math. Dokl. – 1992.¬¬319. – №4. – P. 943–947. (in russian)

2. Rasulov M., Coskun E., Sinsoysal B. A finite differences method for a two-dimensional nonlinear hyperbolic equation in a class of discontinuous functions // Applied mathematics and computation. – 2003.¬140. – №2-3. – P. 279–295.

IDENTIFICATION OF COGNITIVE MAPS WEIGHTS IN THE MULTIRATE MODEL OF CRYPTOCURRENCY APPLICATION

V. Romanenko, H. Kantsedal, Y. Milyavsky
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine
romanenko.viktorroman@gmail.com, g.kantsedal@protonmail.com, yuriy.milyavsky@gmail.com,

Cryptocurrency market is a highly volatile market with lots of factors influencing each other in a dynamic way. Modeling of such a complex system is not easy. Cognitive maps (CM) can be a good tool for analysis, prediction and control of the cryptocurrency application in the financial markets. But in this system nodes coordinates are measured in different time scales which requires building a multirate model of the CM impulse process [1]. When the graph of the CM is built, the problem of estimating the edges weights has to be solved. But it's hard to estimate such them based on expert views only, because the system evolves very quickly and needs to be updates frequently, and because experts find it hard to estimate the multirate system's weights. So the current report states and solves the problem of dynamic identification of the CM adjacency matrix of the multirate model for the cryptocurrency market. Generally, if all nodes are measured (which is true for our case), the least squares method can be used for the identification. But in this case we have two issues which prevent using this method directly. The first issue is that we need to update the coefficients dynamically in real time when they are changed. The second issue is that we need to adapt this method to the multirate case. The solution is to decompose the system into fast and slow subsystems and to apply recursive least squares method separately to each of these subsystems. Slow motions in the fast subsystem and fast motions in the slow subsystems will be considered as disturbances. Simulations demonstrated that standard recursive least squares provide unsatisfactory results in such a case. So the Sherman–Morrison–Woodbury formula with exponential forgetting [2] was used to modify the method for both slow and fast subsystems to get satisfactory weights estimates.

References

1. Romanenko, V., Miliavskyi, Y., Kantsedal, H., (2022) Application of Impulse Process Models with Multirate Sampling in Cognitive Maps of Cryptocurrency for Dynamic Decision Making, *Studies in*

Computational Intelligence, vol 1022. Springer, Cham.
2. Yue Hao, Valeria Simoncini, (2021) The Sherman–Morrison–Woodbury formula for generalized linear matrix equations and applications, *Numerical linear algebra with applications*, vol 28.

THE IMPACT OF M-LEARNING IN EFL CLASSROOMS (BASED ON TEACHING ENGLISH)

Nino Samnidze
Batumi Shota Rustaveli State University, Batumi, Georgia
Nino.samnidze@bsu.edu.ge

It hasn't been long since modern technology has dominated the world and revolutionized the way we interact, work, and act in society. The rapid growth of mobile devices and their smart functions contribute to supporting the learning and teaching process in foreign language classes. Undeniably, the majority of students seem to be occupied with their own electronic devices, mastering all the functions and taking advantage of the benefits devices can offer. Based on the observation of language classes at our university, we deemed the use of mobile devices during classes to be of great importance.

There are myriads of opportunities teachers can employ for creating better, innovative learning environments open to creativity and the challenge it might add to the classroom. The aim of the paper is to work out the best ways mobile devices can be incorporated efficiently at EFL classes which makes learning feasible and gets positive perceptions from students. Also, to make teachers aware of the strategies that can be applied while M-learning. Through playing interactive games based on the target grammar or vocabulary, as well as nice warm-up activities, knowledge consolidation, and revision tasks via mobile phones, students tend to get curious and involved in the process. However, the use of mobile devices in the lessons should be planned thoroughly with clear aims and objectives tailored to students' needs and interests.

The present article deals with all the above issues.

References

1. Didmanidze D., Zoidze K., Akhvlediani N., Tsitskishvili G., Samnidze N., Diasamidze M. Use of computer teaching systems in the learning process.// «Modeling, control and information technologies», V INTERNATIONAL SCIENTIFIC AND PRACTICAL CONFERENCE. 4-6 November 2021. Rivne, Ukraine. Conference materials. – P. 42-43.

ABOUT WEAK CONVERGENCE OF THE OPERATOR EXTRAPOLATION METHOD

V. Semenov, S. Denysov, O. Kharkov
Taras Shevchenko National University of Kyiv, Ukraine
semenov.volodya@gmail.com, denisov.univ@gmail.com, olehharek@gmail.com

Many important problems of operations research, optimal control theory and mathematical physics can be written in the form of variational inequalities.

With the advent of generating adversarial neural networks (GANs), strong interest in the use and investigation of iterative algorithms for solving variational inequalities arose in the ML-community [1].

Non-smooth optimization problems can be solved effectively if they are reformulated as saddle problems, and modern approximate algorithms for solving variational inequalities are applied to the obtained saddle problems [2].

This report is devoted to the study of new iterative algorithms for solving variational inequalities in uniformly convex Banach spaces. The first algorithm is a modification of the forward-reflected-backward algorithm [3], which uses the Alber generalized projection instead of the metric one. The second algorithm is an adaptive version of the first one, where the step size update rule is used, which does not require knowledge of Lipschitz constants and linear search procedure.

For variational inequalities with monotone, Lipschitz continuous operators acting in a 2-uniformly convex and uniformly smooth Banach space, theorems on the weak convergence of methods are proved. Also, for the first algorithm, an efficiency estimate in terms of the gap function is proved

References

1. Gidel G., Berard H., Vincent P., Lacoste-Julien S. A Variational Inequality Perspective on Generative Adversarial Networks. arXiv preprint arXiv:1802.10551. 2018.

2. 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.

3. Malitsky Y., Tam M. K. A Forward-Backward Splitting Method for Monotone Inclusions Without Cocoercivity. // SIAM Journal on Optimization. – 2020. – Vol. 30. – No. 2. – P. 1451-1472.

PROBLEMS OF CHOOSING INFRASTRUCTURE SOLUTIONS FOR ELECTRIC VEHICLES

[1] N.V. Semenova, [2] G.O. Dolenko, [1] D.O. Manovytska
[1]Glushkov Institute of Cybernetics of NAS of Ukraine
[2]Taras Shevchenko National University of Kyiv, Ukraine
nvsemenova@meta.ua, **galyna.dolenko@gmail.com, manovytska_dariia@ukr.net**

With the continuing trend of popularization of electric vehicles, increasing driving range and reducing cost and maintenance costs, electric vehicles continue to improve and spread as a new transport option, which creates excellent opportunities for the development of a "smart city" in terms of electrification of transport. The number of challenges in planning the location and capacity of charging stations for electric vehicles is expanding.

Departing from generalized studies of global charging station infrastructure to ensure a competitive strategy in the future, the study proposes a market mechanism for the problem of planning the location of charging stations at a more local level, using the example of the city of Kyiv. The presented "predict-optimize" diagram will help to predict the demand for charging for electric vehicles using the forecasting functionality of the MS Excel software application in conjunction with other calculations and analysis, as well as to optimize a competitive resource allocation strategy for planning the location of charging stations using the economic model of market competition by Antoine Cournot [1].

To find an equilibrium according to the Cournot model, a parallel computation algorithm with convergence analysis is proposed. The problem of optimizing the number of charging stations for each of the market participants, companies providing charging services for electric vehicles in each of the parts (zones) of the city is also presented. The study was conducted using data on transport in Kyiv and relevant key socio-economic indicators [2].

References

1. Antoine Augustin Cournot. Revue sommaire des doctrines économiques 1877. Economics. – 339 p.(in French)
2. Як в Україні розвивається інфраструктура зарядок для електромобілів|РБК-Україна [Електронний ресурс]. Режим доступу:https://auto.rbc.ua/ukr/show/zaryadnaya-infrastruktura-637906584.html.

CONDITIONS FOR SOLUBILITY OF MULTI-CRITERION PROBLEMS OF LEXICOGRAPHIC OPTIMIZATION ON AN UNBOUNDED FEASIBLE SET

[1]Semenova N.V., [2]Lomaha M.M., [1]Semenov V.V.
[1]Glushkov Institute of Cybernetics of NAS of Ukraine
[2]Uzhhorod National University, Ukraine
nvsemenova@meta.ua, **mariia.lomaha@uzhnu.edu.ua,**
semenov.jr@gmail.com

Let us consider the lexicographic optimization problem: $Z_L(F,X)$: $\max^L\{F(x)|x\in X\}$, where $F(x)=(f_1(x),...,f_\ell(x))$, $\ell\geq 2$, $f_k(x)=\langle c_k,x\rangle$, $c_k\in R^n$, $k\in N_\ell=\{1,2,...,\ell\}$, $X=\{x\in R^n|g^i(x)\leq 0, x\geq 0, i\in N_m\}$, $X\neq\varnothing$, $g^i(x), i\in N_m$ are convex functions. The unboundedness of the convex set X means that $0^+X\setminus\{0\}\neq\varnothing$, where $0^+X=\{y\in R^n|\forall x\in X: x+ty\in X, t\geq 0\}$ is a recessive cone of the set X. We will analyze the problem $Z_L(F,X)$ taking into account the properties of the recessive cone 0^+X and of the cone $K^L=\{x\in R^n|Cx>^L 0\}$ of perspective lexicographic directions of the problem $Z_L(F,X)$. In the case of a convex closed unbounded feasible set X of the problem $Z_L(F,X)$ the theorem is valid.

Theorem 1. A necessary condition for the existence of lexicographically optimal solutions to the problem $Z_L(F,X)$ is the empty intersection of the cone K^L of perspective lexicographic directions and the recessive cone 0^+X, that is

$$K^L\bigcap 0^+X=\varnothing. \qquad (1)$$

Theorem 2. Let the feasible set X of the problem $Z_L(F,X)$ be a closed convex polyhedral set. A necessary and sufficient condition for the existence of lexicographically optimal solutions to this problem is the fulfillment of equality (1).

It should be noted that the multifaceted condition of a convex closed unbounded set X is essential for the statement of the fact that condition (1) is a necessary and sufficient condition for the existence of lexicographically optimal solutions to the problem $Z_L(F,X)$.

References

1. Semenova N.V., Lomaha M.M. On existence and optimality of solutions of

a vector problem of lexicographic convex optimization with linear of criteria functions. // Uzhgorod University Scientific Bulletin. Series: Mathematics and Informatics. – 2020. – Vol. 37(2). – P. 19−127 (in Ukrainian).
2. Semenova N.V., Lomaha M.M., Semenov V.V. Exictence of solution and solving method of lexicographic problem of convex optimization with the linear function of criteria. // Dopov. Nac. akad. nauk. Ukr. – 2020. – Vol. 12. – P. 19−27 (in Ukrainian).

FUNCTIONAL INTERVAL OF A FUNCTION WITH KNOWN RESTRICTIONS OF ITS DERIVATIVE BY MONOTONIC FUNCTIONS

P.S. Senio
Ivan Franko National University of Lviv, Ukraine
petrosny@ukr.net

Two-sided approximations of the function are constructed when its analytical expression is unknown and some incomplete information about it is known. This is the basis for the construction of methods for solving initial and boundary value problems for ordinary differential equations.

Let the function $y(x)$ of n times be continuously differentiable at each point x of the interval $[a,b]$, the functions $\underline{u}(x)$, $\overline{u}(x)$ are monotonic and such that on this interval the double inequality holds $\underline{u}(x) \le y^{(n)}(x) \le \overline{u}(x)$, where $y_a^{(i)} = y^{(i)}(a)$, $y_b^{(i)} = y^{(i)}(b)$, $(i = \overline{0, n-1})$.

Then, depending on the type of monotonicity of the functions $\underline{u}(x)$, $\overline{u}(x)$, parity of the number n and at which end of the interval $[a,b]$ the boundary conditions are known, it is possible to construct the functional interval of such a function $y(x)$.

In particular, if the number n is odd and the function $\overline{u}(x)$ is monotonically increasing on the interval $[a,b]$, and the function $\underline{u}(x)$ is monotonically decreasing and the boundary conditions at the point a are known, then

$$y_a + y'_a \cdot (x-a) + \frac{1}{2} \cdot y''_a \cdot (x-a)^2 + \cdots + \frac{1}{n!} \cdot \underline{u}(x) \cdot (x-a)^n \le y(x) \le$$

$$y_a + y'_a \cdot (x-a) + \frac{1}{2} \cdot y''_a \cdot (x-a)^2 + \cdots + \frac{1}{n!} \cdot \bar{u}(x) \cdot (x-a)^n .$$

But, if the number n is even and the function $\bar{u}(x)$ is monotonically increasing on the interval $[a,b]$, and the function $\underline{u}(x)$ is monotonically decreasing, and the boundary conditions at the point b are known, then

$$y_b + y'_b \cdot (x-b) + \frac{1}{2} \cdot y''_b \cdot (x-b)^2 + \cdots + \frac{1}{n!} \cdot \underline{u}(b) \cdot (x-b)^n \le y(x) \le$$

$$y_b + y'_b \cdot (x-b) + \frac{1}{2} \cdot y''_b \cdot (x-b)^2 + \cdots + \frac{1}{n!} \cdot \bar{u}(b) \cdot (x-b)^n .$$

THE QUALITY OF KNOWLEDGE. STATISTICAL APPROACH

M. Sharapov
Taras Shevchenko National University of Kyiv, Ukraine
boxus@ukr.net

Almost always, when talking about assessing the quality of knowledge, indicators such as grades, scores and ratings are considered. In article (1), both methods of statistical correction of test results and a new sub-indicator of knowledge strength k are proposed. To implement the highlighted idea, the tests in question should have a somewhat specific structure, namely, along with the standard list of answer options, a special "I don't know" answer option. Then

$$k = \begin{cases} \dfrac{Cn-(N-D)}{(n-1)(N-D)}, & 0 < \dfrac{N-D}{n} < C \le N-D, \\ 0, & 0 \le C \le \dfrac{N-D}{n}, \end{cases}$$

where C denotes correct answers; n is the number of answer options in addition to IDK; D is the number of IDK answers; N is the number of questions. One can offer many appropriate modifications for k, e.g. $k' = \dfrac{C}{N-D}$, $D < N$. Despite its simplicity k' has got some unique and interesting properties. For example, the dependence of the given coefficients on the level $\alpha \in [0,1]$ of the student's knowledge and on the level $\beta \in [0,1]$ of the desire to guess the correct answer is quite interesting. Under the given conditions, the vector (C, D, N-C-D) has a

trinomial distribution, and the mentioned coefficients are random functions of this vector. Thus, it is worth mentioning the optimization problems within the limits of possible strategies that arise under these conditions. Through $\alpha \in [0,1]$ and $\beta \in [0,1]$, the student will want to maximize the value of $k = k(\alpha, \beta)$ or its average value.

This approach outlines further possible directions of its development. Currently, one important question remains open - whether it is possible to introduce similar assessments within the framework of ordinary classical tests.

References

1. Sharapov M. Statistical corrections of test results. // Bulletin of Taras Shevchenko National University of Kyiv, Series Physics & Mathematics. – 2015. -- Vol.2.

INTELLECTUAL ANALYSIS OF REACTIONS TO NEWS BASED ON DATA FROM TELEGRAM CHANNELS

I.M. Shevchuk [1,2], O.G. Nakonechnyi[1], O.A. Kapustian[1,2], O.Yu. Kosukha[1], M.V. Loseva[1]

[1] Taras Shevchenko National University of Kyiv, Ukraine

[2] The University of L'Aquila, Italian Republic

iuliia.shevchuk@knu.ua, iuliia.shevchuk@univaq.it

Natural Language Processing (NLP) of messages in Telegram channels can be reduced to previously developed natural language processing algorithms.

But for the Ukrainian language, there is still a relatively small number of marked data sets, including meaningful dictionaries of the tonality of the Ukrainian language (they are currently at the initial level of formation). It is also necessary to note the need for research on developing tools for analyzing reactions. Telegram itself does not currently offer this functionality as a part of analytics for Telegram channels. Such studies are especially relevant with the increasing popularity of Telegram as an uncensored platform for spreading news and fakes.

Therefore, we used algorithms of intellectual analysis to develop a method of researching news and reactions to them in Telegram channels. In particular, the features of collecting and pre-processing datasets for the system, the methodology of thematic analysis of the received data,

and the model used to obtain predictions of reactions to Telegram messages depending on their text are described.

Acknowledgments. The presented paper has been partially supported by the Ukrainian-Lithuanian R&D project "Modeling the role of human potential to ensure the country's defense during the latest threats" (Registration number 0122U002629).

References

1. Ramasamy, L. K., Kadry, S., Nam, Y., & Meqdad, M. N. (2021). Performance analysis of sentiments in Twitter dataset using SVM models. *Int. J. Electr. Comput. Eng*, *11*(3), 2275-2284.

2. Gunawan, T. S., Babiker, A. B. F., Ismail, N., & Effendi, M. R. (2021, August). Development of Intelligent Telegram Chatbot Using Natural Language Processing. In *2021 7th International Conference on Wireless and Telematics (ICWT)* (pp. 1-5). IEEE.

3. Karimpour, D., Chahooki, M. A. Z., & Hashemi, A. (2021, March). User recommendation based on Hybrid filtering in Telegram messenger. In *2021 26th International Computer Conference, Computer Society of Iran (CSICC)* (pp. 1-7). IEEE.

MODELING OF PRODUCTION PROCESSES

Zaza Shubladze

Batumi State Maritime Academy, Batumi, Georgia

Modeling of production processes has emerged as an independent scientific direction in operations research. Since the 1960s, methods for modeling production processes and operations research have been developing more intensively. The general mathematical basis for the development of these methods was linear, non-linear, geometric programming methods.

On the basis of Monte Carlo methods and Markov processes, methods for mathematical modeling of production processes have been developed, taking into account the probabilistic nature of the change in acting factors. On the basis of Monte Carlo methods and Markov processes, methods for mathematical modeling of production processes have been developed, taking into account the probabilistic nature of the change in acting factors. Probabilistic methods for studying production processes have become an independent science - operations research. As an integral part of operations research, which is developed on the basis of Markov random processes, is considered the queuing theory,

represented by fundamental research.

Based on generally accepted methods of mathematical modeling of production processes and operations research, methods for modeling agricultural production processes have been further developed.

The processing of experimental and statistical data was carried out according to well-known methods and recommendations set forth in a number of general guidelines.

The methodology for conducting experiments was drawn up in full accordance with the general methods for conducting experimental studies.

All production processes can be described by a limited number of generalized mathematical models, which allow us to analyze the influence of the main factors on the main performance indicators of the respective units, taking into account the probabilistic nature of the change of these factors over the entire practical range.

The present article deals with all the above issues.

SYSTEM OF LINEAR DIFFERENTIAL EQUATIONS WITH PIECEWISE CONSTANT COEFFICIENTS

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

A system of linear differential equations with piecewise constant coefficients

$$\frac{dX(t)}{dt} = A(\zeta(t))X(t), \tag{1}$$

is considered. We assume that at $\zeta(t) = \theta_k$ the system of equations (1) takes the form

$$\frac{dX(t)}{dt} = A_k X(t), \quad A_k \equiv A(\theta_k), \quad (k = 1,...,n). \tag{2}$$

These systems of equations have fundamental matrices of the solutions

$N_k(t) = e^{A_k t} \quad (k = 1,...,n).$

Let the semi-Markov random process $\zeta(t)$ be determined by given intensities $q_{ks}(t) \quad (k, s = 1,...,n)$. The system of integral moment

equations takes the form

$$M_k(t) = \psi_k(t)e^{A_k t}M_k(0) + \int_0^t \psi_k(t-\tau)e^{A_k(t-\tau)}V_k(\tau)d\tau;$$

$$V_k(t) = \sum_{s=1}^{n} q_{ks}(t)C_{ks}e^{A_s t}M_s(0) + \int_0^t \sum_{s=1}^{n} q_{ks}(t-\tau)C_{ks}e^{A_s(t-\tau)}V_s(\tau)d\tau;$$

$$(k = 1,...,n). \tag{3}$$

Similarly, the system of moment equations for second-order moments takes the form

$$D_k(t) = \psi_k(t)e^{A_k t}D_k(0)e^{A_k^* t} + \int_0^t \psi_k(t-\tau)e^{A_k(t-\tau)}W_k(\tau)e^{A_k^*(t-\tau)}d\tau;$$

$$W_k(t) = \sum_{s=1}^{n} q_{ks}(t)C_{ks}e^{A_s t}D_s(0)e^{A_s^* t}C_{ks}^* +$$

$$+\int_0^t \sum_{s=1}^{n} q_{ks}(t-\tau)C_{ks}e^{A_s(t-\tau)}W_s(\tau)e^{A_s^*(t-\tau)}C_{ks}^* d\tau;\ \ (k = 1,...,n). \tag{4}$$

Consider the case when the semi-Markov process $\zeta(t)$ coincides with some Markov process defined by the system of differential equations

$$\frac{dP_k(t)}{dt} = \sum_{s=1}^{n} a_{ks}p_s(t),\ \ (k = 1,...,n). \tag{5}$$

In this case, the intensities $q_{ks}(t)$ are determined at $a_{kk} < 0$ $(k = 1,...,n)$ by the formulas

$$q_{kk}(t) \equiv 0,\ \ q_k(t) = -a_{kk}e^{a_{kk}t},\ \ \psi_k(t) = e^{a_{kk}t},$$

$$q_{sk}(t) = a_{sk}e^{a_{kk}t},\ \ (s \neq k; s,k = 1,...,n). \tag{6}$$

We arrive at the system of integral equations

$$M_k(t) = e^{a_{kk}t}e^{A_k t}M_k(0) + \int_0^t e^{a_{kk}(t-\tau)}e^{A_k(t-\tau)}V_k(\tau)d\tau;$$

$$V_k(t) = \sum_{\substack{s=1 \\ s \neq k}}^{n} a_{ks} C_{ks} (e^{a_{ss}t} e^{A_s t} M_s(0) + \int_0^t e^{a_{ss}(t-\tau)} e^{A_s(t-\tau)} V_s(\tau) d\tau); \ (k = 1,..., n).$$

(7)

Comparing the right parts in the system of equations (7), we arrive at systems of vector equations

$$V_k(t) = \sum_{\substack{s=1 \\ s \neq k}}^{n} a_{ks} C_{ks} M_s(t); \ \ (k = 1,..., n).$$

We exclude the vector $V_k(t)$ from the first equation of system (7), we arrive at the system of integral equations

$$M_k(t) = e^{a_{kk}t} e^{A_k t} (M_k(0) + \int_0^t e^{-a_{kk}\tau} e^{-A_k \tau} \sum_{\substack{s=1 \\ s \neq k}}^{n} a_{ks} C_{ks} M_s(\tau) d\tau); \ (k = 1,..., n).$$

(8)

Differentiating the system of equations (8) with respect to t we arrive at the system of differential equations

$$\frac{dM_k(t)}{dt} = A_k M_k(t) + \sum_{s=1}^{n} a_{ks} C_{ks} M_s(t), \ \ (k = 1,..., n). \qquad (9)$$

Note that the systems of equations (7), (10) can be studied using the Laplace transform.

References

1. Valeev K.G., Karelova O.L., Gorelov V.I. Optimization of linear systems with random coefficients. – M., izd. RUDN, 1996. – 258 p.
2. Kats I.Ya., Krasovsky N.N. On the stability of systems with random parameters. // Applied Mathematics and Mechanics. – 1960. – N5. – P.809-823.
3. Nakonechnyi O. G., Demidenko S.V., Shusharin Yu.V. Guaranteed estimates of the mean of random sequences.// Visnik Taras Shevchenko National University of Kyiv: Seria fiz.-mat. nauk. – 2014. – №4. – P.204-208.
4. Shusharin Yu.V. Recurrent equations for characteristic functions of solutions of linear difference equations with random coefficients.// Visnik Taras Shevchenko National University of Kyiv: Seria fiz.-mat. nauk. – 2014. – №3. – P.206-209.
5. Shusharin Yu.V. Algebraic criteria for asymptotic stability of solutions of linear difference equations with random coefficients.// Obchisluvana ta prikladna matematika. – 2014. – №1. – P.167-175.

ON-LINE NON-STATIONARY PARAMETER IDENTIFICATION BY THE LEAST SQUARES METHOD WITH VARIABLE FORGETTING FACTOR AND LEAST DEVIATIONS FROM 'ATTRACTION' POINTS FOR NON-LINEAR DYNAMIC OBJECTS UNDER NON-CLASSICAL ASSUMPTIONS

A.S. Slabospitsky
Taras Shevchenko National University of Kyiv, Ukraine
sl@univ.kiev.ua

The parameter estimation problem of slowly time-varying vector α is investigated for non-linear discrete dynamic system.

Suppose that state equation is linear in parameter vector α and has additive disturbance vector $\xi(k)$. Additionally, 'attraction' point $\alpha_*(k)$ is known at any moment k, $k = 0,1,2,\ldots$.

The least squares estimate with variable forgetting factor $\lambda(k)$ $\left(\lambda(k) \in (0,1],\ k \in \mathbb{N}\right)$ is studied for above-mentioned object under non-classical assumptions when this estimate may be not unique.

The set of all such estimates is defined as

$$\operatorname*{Arg\,min}_{\alpha} Q(\alpha, N),$$

where $Q(\alpha, N) = \sum_{k=1}^{N} w(k,N) \left\| \xi(k) \right\|^2$,

$$w(k,N) = \begin{cases} \prod_{i=k}^{N-1} \lambda(i), \ if \ k = \overline{1, N-1}, \\ 1, \ if \ k = N. \end{cases}$$

The desired unique estimate $\hat{\alpha}(N)$ on before-mentioned set of estimates is suggested as least squares estimate with variable forgetting factor $\lambda(\bullet)$ and least deviation from given 'attraction' point $\alpha_*(N)$ at any moment N in this situation.

Explicit formula for estimate $\hat{\alpha}(N)$ is obtained using the Moore-Penrose pseudo-inverse operator.

To recalculate this estimate online, a recurrent form of its representation is proposed, which no longer requires the Moore-Penrose pseudo-inversion of the matrices. The recurrent procedure for corresponding weighted residual sum of squares is derived too.

USING THE INDUSTRIAL INTERNET OF THINGS(IIOT) IN HIL SIMULATION

D. Sokhan
Glushkov Institute of Cybernetics NAS of Ukraine
dsokhan@gmail.com

The Industrial Internet of Things (IIoT) is principle of the technology is that initially sensors, actuators, controllers and man-machine interfaces are installed on key parts of the equipment, after which information is collected, which subsequently allows the company to acquire objective and accurate data on the state of the enterprise. Processed data is delivered to all departments of the enterprise, which helps to establish interaction between employees of different departments and make informed decisions. Internet-connected devices use built-in sensors to collect data and, in some cases, act on it. IoT-connected devices and machines can improve the way we work and live. Internet of Things (IoT) application examples range from a smart home that automatically regulates heating and lighting to a smart factory that monitors industrial machines to find problems and then automatically adjusts to avoid failures.

IIoT is a large number of "things" that are connected to the Internet to communicate with other things: IIoT applications, connected devices, industrial machines, and more. Internet-connected devices use built-in sensors to collect data and, in some cases, act on it. For example, it monitors industrial machines to find problems and then automatically adjusts itself to avoid failures.

An essential part of the IIoT infrastructure are mobile applications that are built to better integrate with other connected devices. They must, on the one hand, interact with other parts of the system; on the other hand, they must realize the benefits of applications, namely portability, intuitive use and seamless integration into daily routine activities. A: Mobile phone mobility ensures that its user has 24/7 access to control the IIoT system. Today, almost everyone, including industrial workers, has a smartphone that provides round-the-clock access to connected infrastructure, i.e. use of any industrial IIoT system is monitoring. An enterprise can improve its preventive maintenance policy by installing an efficient enterprise IIoT solution and providing its employees with a real-time monitoring application on top of it. These applications are a dashboard that allows users to view hardware performance data in the form of charts, charts, and graphs, and receive alerts if something goes wrong.

ALGORITHMS OF INTELLECTUAL COLLECTION AND TRANSMISSION OF INFORMATION IN DYNAMIC SYSTEMS OF SEMI-NATURAL MODELING OF COMPONENTS AND OBJECTS OF MODELINGS

K. Sosnenko, T. Samoliuk
Glushkov Institute of Cybernetics NAS of Ukraine
sosnenko.kate@ukr.net, **tamara.samoliuk@ukr.net**

Algorithms for intelligent collection and transmission of information in dynamic systems of semi-natural modeling of components and objects of modeling have been developed. A feature of the developed method is the ability to assess the actual characteristics of the operated system in the full range of possible changes in external influences, which cannot always be achieved by field experiments. In addition, this method eliminates the uncertainty that is found in simulation, due to the impossibility of accurate mathematical description of the system. The developed method combines syntactic and neural network recognition methods for a wide class of graphic images. Graphic images of block diagrams belong to the class of graphological, in particular, patent documentation and contain many figures of the class, for example, MS Office autoshapes. The figures have internal and external blocks of text and are connected by communication lines that form nodes between themselves and with the contour lines.

Block diagram structure recognition is a necessary component for modern computer-aided design systems. The main procedures of the Block diagram image recognition algorithm have been partially tested at the software level, and allow us to conclude about the effectiveness of the proposed structural methods.

Convolutional neural networks have been used successfully to solve computer vision problems. The main difficulties in neural network recognition are transferred to the preparation of training and test data sets and partly to a fairly long process of machine learning. It is proposed to use GAN (Generative Adversarial Nets) competitive neural networks in the preparation of training data for neural networks.

As result of this work, it was proved that an increase in the level of error recognition can be reducing the promotion step and involving statistical processing of scan results.

A MARKOV CHAIN IN SUPPLY CHAIN MANAGEMENT

D. Symonov
V.M. Glushkov Institute of Cybernetics NAS of Ukraine
denys.symonov@gmail.com

The flow of inventory items within the supply chain has a probabilistic parameter of process [1]. The number of process states can be either finite or infinite. The state of the development parameters of the process fully depends on the parameters the previous process, that is, there is a pronounced consistent process flow. It is possible to level the hard impact of the previous stage on the current one by creating buffers (warehouses with safety stock), but this can negatively affect the final cost and increase the working capital.

The chronological sequence of a stochastic variable characterizing the state of the parameters of the processes $\left\{V_{t_n}\right\}$ at discrete times $\left\{t_k\right\}$, $k=\overline{1,n}$, can be written as follows [2]:

$$P\left\{V_{t_n}=v\,|\,V_{t_{n-1}}=v_{n-1},V_{t_{n-2}}=v_{n-2},\ldots,V_{t_0}=v\right\}, \tag{1}$$

so,

$$P\left\{V_{t_n}=v\,|\,V_{t_{n-1}}=v_{n-1}\right\}. \tag{2}$$

Expression (1) demonstrates the full compliance of the supply chain with the properties of the Markov process.

Accordingly, the probabilities at a certain point in time t_k can be written in the following form:

$$p_{ij}=P\left\{V_t=j\,|\,V_{t-1}=i,\ i=\overline{1,n}\ ,\ j=\overline{1,n},t=\overline{1,T}\right\}, \tag{3}$$

so,

$$\sum p_{ij}=1,\forall(i),\ i=\overline{1,n},\ p_{ij}\geq 0,\forall(i)\wedge\forall(j). \tag{4}$$

The single-rank matrix of transition probabilities will have the following form:

$$P=\left(p_{ij}\right),p_{ij}\neq\varnothing,i=\overline{1,n},\ j=\overline{1,n}. \tag{5}$$

The main property of the matrix P is the presence of fixed parameters of the transition probabilities p_{ij}, which do not depend on time.

References

1. P.S. Knopov, A.S. Samosenok. On some applied problems of Markov random processes with local interaction. // Cybernetics and System

Analysis, 2011, (3). 15-32 page. (in ukrainian)
2. Hamdy A. Taha. Operations Research: An Introduction. 10th Ed. -NJ: Pearson Education Inc., 2017. - 849 pages.

DECISION TREES IN PYTHON WITH SCIKIT-LEARN

Y. Tupalo
Glushkov Institute of Cybernetics NAS of Ukraine
Typaloyaroslav91@gmail.com

A decision tree is one of the most commonly and widely used supervised machine learning algorithms that can perform both regression and classification tasks. The intuition behind the decision tree algorithm is simple yet very powerful. For each attribute in the dataset, the decision tree algorithm generates a node where the most important attribute is placed at the root node. For evaluation, we start at the root node and work our way down the tree, following the appropriate node that satisfies our condition or “decision”. This process continues until the end node containing the prediction or decision tree result is reached.

It may seem a bit complicated at first, but you probably don't realize that you've been using decision trees to make decisions all your life without even knowing it. Imagine a situation where a person asks you to lend him a car for a day and you have to make a decision whether to lend him a car or not. There are several factors that help determine your decision, some of which have been listed below:

- Is this person a close friend or just an acquaintance? If the person is just an acquaintance, then decline the request; if the person is a friend, then go to the next step.
- A person asks for a car for the first time? If so, lend them a car, otherwise, move on to the next step.

Using decision trees for predictive analysis has a number of advantages:

- Decision trees can be used to predict both continuous and discrete values, i.e. they work well for both regression and classification problems.
- They require relatively less effort to train the algorithm.
- They can be used to classify non-linearly separable data.
- They are very fast and efficient compared to KNN and other classification algorithms.

THE WIRELESS INFRASTRUCTURE OF THE SYSTEM BASED ON ZIGBEE NETWORKS FOR HIL SIMULATION

O. Tymashov
Glushkov institute of cybernetics NAS of Ukraine
alex_timashov@outlook.com

Recently, wireless sensor networks have become increasingly widespread and important. Networks that, by their purpose, parameters, specifications, differ significantly from communication networks. Many applications require wireless networks that are not high speed but are reliable, robust (self-healing), easy to deploy and easy to operate. It is also important that the equipment of such networks allows long-term operation from autonomous power sources, has a low cost, and is compact. The IEEE 802.15.4 and ZigBee standards were created to describe robust, scalable, multi-hop wireless networks that are easy to deploy and support a variety of applications. ZigBee networks fully satisfy: Thanks to the mesh network topology and the use of special routing algorithms, the ZigBee network provides self-healing and guaranteed packet delivery in case of a break in communication between individual nodes (appearance of an obstacle), overload or failure of some element; ZigBee devices are characterized by low power consumption, especially end devices for which a “sleep” mode is provided, which allows these devices to work up to three years from one ordinary AA and even AAA battery; ZigBee devices are compact and relatively inexpensive. Communication in the ZigBee network is carried out by sequential relaying of packets from the source node to the destination node. The ZigBee network provides several alternative routing algorithms, the selection of which occurs automatically. The price that had to be paid in ZigBee networks for minimizing power consumption, compactness and low cost is a relatively low data transfer rate. Speed (including service information) is 250 kbps. The average payload data transfer rate, depending on the network load and the number of retransmissions, ranges from 5 to 40 kbps. The distance between network workstations is tens of meters indoors and hundreds of meters outdoors. Due to relaying, the area covered by the network can be very significant: up to several thousand square meters indoors and up to several hectares in open space. Moreover, the ZigBee network can be expanded at any time by adding new elements or, on the contrary, divided into several zones by simply assigning an appropriate number of new network configurators. This can be useful for reducing the load and, accordingly, increasing the data transfer rate.

USE OF SUBCLASSES OF SOLVABLE PROBLEMS TO EVALUATE OF THE ACCURACY OF THE ALGORITHM

Nadija Tymofijeva
International Scientific and Training Center for Information Technologses and Systems, Ukraine
tymnad@gmail.com

Much of the enumeration problems, which are combinatorial optimization problems are *NP* -complete. Many methods and algorithms, both exact and approximate, have been developed to solve them. These methods and algorithms require a partial search of options, so it is difficult to assess their accuracy.

In the literature for some classes of combinatorial optimization problems, subclasses are described that have a certain structure of input information, for which the method of analytical finding of the global solution is known. Estimation of accuracy of a certain algorithm we spend, whiz using subclasses of solvable problems. For example, when solving combinatorial optimization problems using the methods of "greedy" algorithm and the nearest neighbor, the formation of the solution (combinatorial configuration) begins with the largest (or smallest) element of a matrix, which sets the input data. However, since these methods do not analyze the factors that affect the value of the objective function depending on the combination of input values, the result obtained by these approaches is usually far from optimal. Using subclasses of solvable problems, it is shown that they can be used to find the global minimum in the case of maximization or the global maximum in the case of minimization of the objective function. Estimation of the accuracy of solving the problem at a known global minimum is calculated by expression $\Delta(F_{\min}, F(w^{k*})) = \left(1 - F_{\min} / F(w^{k*})\right)100\%$ (or $\Delta(F_{max}, F(w^{i*})) = \left(1 - F(w^{i*}) / F_{max}\right)100\%$ in the case of maximization), where $F_{\min}$ – the global minimum of the problem, $F_{\max}$ – respectively, its global maximum, $F(w^{k*})$, $F(w^{i*})$ – obtained minimum or maximum solutions of a problem by the selected algorithm (method).

References

1. Тимофієва Н.К. Доведення збіжності алгоритмів комбінаторної оптимізації з використанням підкласів розв'язних задач. *УСиМ*. 2016. № 2. С.5 – 21, 27.

APPROXIMATION OF THE SOLUTION IN THE PROBLEM OF DISTRIBUTION OF POLLUTANTS IN SOIL LAYERS USING THE ALGORITHM OF DIFFERENTIAL EVOLUTION

I. Vergunova
Taras Shevchenko National University of Kyiv, Ukraine
vergunova@bigmir.net

The work is devoted to the search for effective methods of numerical solution of partial differential equations [1]. Finite-difference methods, the finite element method are cumbersome and require quite large resources. Consideration of the appropriate optimization problem and the transition to the use of neural network approaches involves finding the optimum of the objective function with a large number of variables using gradient methods. It is characterized by the presence of the problem of local minima. Therefore, it is logical to try to approximate the solution of such problems using the algorithm of differential evolution [2].

We present the problem in the form of an optimization, where the function that must be optimized is:

$$\Im(\tilde{u},\theta) = \left\|Z\tilde{u} - f\right\|^2_{L_2(Q)} + \left\|B\tilde{u}\right\|^2_{L_2(\partial\Omega\times[0,T])} + \left\|\tilde{u}(x,0)\right\|^2_{L_2(\Omega)} \to \min, \qquad (1)$$

where

$$Zu \equiv \frac{\partial u}{\partial t} + Lu \equiv \frac{\partial u}{\partial t} - \sum_{i=1}^{2} \frac{\partial}{\partial x_i}\left(D(x)\frac{\partial u}{\partial x_i}\right) + \sum_{i=1}^{2} V\frac{\partial u}{\partial x_i} = -u_0\varphi(x)\delta(t-0),$$

$$u(x,0) = 0, \quad x \in \Omega, \; Bu \equiv \left(-\sum_{i=1}^{2} D\frac{\partial u}{\partial x_i} + Vu\right)\Big|_{x\in\partial\Omega} = 0, \; t \in [0,T],$$

$$\tilde{u}(x,t;\theta) = \sum_{i=1}^{N} c_i e^{-\omega_{1i}(x_1-x_{1i})^2-\omega_{2i}(x_2-x_{2i})^2-\omega_{3i}(t-t_i)^2},$$

$u(x,t)$ – the concentration of Cs-137 in point $x=(x_1,x_2)\in\overline{\Omega}$ at moment t, $Q=\Omega\times(0\le t\le T), \Omega\subset R^2$ with piecewise smooth boundary $\partial\Omega$, $\varphi(x)$ – the function describing the surface Γ, u_0 – surface contamination, $\alpha(\Gamma)$ – the slope of the segment of Γ, $D(x)$ – the effective diffusion coefficient; V – the speed of directed diffusion movement, $\theta = \left(\varpi_{ji}\big|_{j=\overline{1,3},i=\overline{1,N}}, c_i\big|_{i=\overline{1,N}}\right)$ – the vector of search parameters.

After replacing the variables, we proceed to consider the area

$\hat{Q} = [0,1]^3$ for a single component of the rampart-terrace with the slope α.

We took 3 sequences of N_1 random numbers evenly distributed over [0,1]: $\{x_1'^{(1)},...,x_1'^{(N)}\}$, $\{x_2'^{(1)},...,x_2'^{(N)}\}$, $\{t'^{(1)},...,t_1'^{(N)}\}$. Let's consider the points $M_{1i}(x_1'^{(i)}, x_2'^{(i)}, t'^{(i)}\}$, $M_{02i}(0, x_2'^{(i)}, t'^{(i)}\}$, $M_{12i}(1, x_2'^{(i)}, t'^{(i)}\}$, $M_{30i}(x_1'^{(i)}, 0, t'^{(i)}\}$, $M_{31i}(x_1'^{(i)}, 1, t'^{(i)}\}$, $M_{ti}(x_1'^{(i)}, x_2'^{(i)}, 0\}$ to calculate the function (1).

We randomly generate the initial generation of the population for $\theta = \left(\varpi_{ji}\big|_{j=\overline{1,3}, i=\overline{1,N}}, c_i\big|_{i=\overline{1,N}} \right)$ on [0,1] for a given N_2.

Then, we create a new generation based on the old one and get a mutant vector at each iteration. Namely for the base vector $\theta^{old}{}_l, l = \overline{1, N_1}$, from the old generation we choose 3 random ones that do not coincide with it, and based on them we create a mutant vector

$$\tilde{\theta}_a = \theta^{old}{}_a + \gamma(\theta^{old}{}_b - \theta^{old}{}_d),$$

where γ – mutation force. Given the probability of crossing, we determine the coordinates of the test vector $\theta^{pr}{}_l, l = \overline{1, N_1}$, which inherits a genetic trait distorted by the mutation from the $\theta^{old}{}_a$.

For each obtained vector $\theta_l, l = \overline{1, N_1}$ we calculate function (1). In the new generation we include the vector ($\theta^{pr}{}_l, l = \overline{1, N_1}$ or base) for which the value of function (1) is smaller.

The work of the algorithm is completed if either $\Im(\tilde{\theta}, \bar{\theta}) \le \varepsilon$, where ε is a predetermined small number, or reached a given maximum number of generations of the population, or the relative scatter of the values of the objective function $\max\limits_{l=\overline{1,N_1}} \Im(\tilde{\theta}, \theta_l) - \min\limits_{l=\overline{1,N_1}} \Im(\tilde{\theta}, \theta_l) < \delta \min\limits_{l=\overline{1,N_1}} \Im(\tilde{\theta}, \theta_l)$ for a fairly small given δ.

Given the probabilistic nature of the algorithm, we perform a set of algorithm starts.

References

1. Vergunova I. Dynamic control of the water erosion for hydrotechnical ramparts-terraces / I. Vergunova // ASTESJ. – 2021. – Vol. 6. – N. 2. – P. 448-457.

2. Wong J. C. Can Transfer Neuroevolution Tractably Solve Your Differential Equations? / J. C. Wong, A. Gupta, Y.-S. Ong // IEEE Computational Intelligence. – 2021. – Vol. 16. – N.2. – P. 14-30.

ANALYTICAL-COMPUTER MODELING IN INVENTORIES CONTROL

O. Voina
Taras Shevchenko National University of Kyiv, Ukraine
avoina@hotmail.com

The key issue in formation of logistics management strategies is to establish optimal stock levels. These stocks must ensure the efficient functioning of the system. The real logistical processes of raw materials moving take place in conditions of uncertainty. This makes it difficult to solve the problem of establishing the optimal level of stocks. Therefore, a mandatory element of any automated logistics system is a block of methodological support for the process of choosing management decisions. The mathematical methods of the analysis the different inventory management models are the theoretical basis of this block. Any formal model of the logistics system is not an accurate description of the real process, but only its approximation. Therefore, a management strategy based on a formal model will only be an approximation to a "better strategy". This means that from a practical point of view, you should choose strategies that are "convenient to use" and "close" to the "best".

In this work the inventory control model which operate in conditions of uncertainty are considered. In addition, several general approaches to building strategies "close" to optimal for similar models are proposed. This is the simplifications of the model by eliminations of some conditions of uncertainty. The additional elements of uncertainty may be introduced into the deterministic model. After that the appropriate solutions for the deterministic model must be generalized. An approach based on the methodology of analytical-computer modeling is considered too. All the proposed approaches are illustrated by the deferent examples of inventory control models with external supply of resources. Such models are characterized by the presence of the regeneration moments. In case of uncertainty in demand insufficient stock levels can lead to losses due to their shortages. On the other hand, the excessive size of the reserve requires an increase in storage costs. In this work the exact answer for the optimal stock level under the condition of uniform distribution of demand is obtained. For other distributions of demand the analytical-computer modeling algorithm of approximate solution is proposed.

ACTUAL PROBLEM OF MODERN DEVELOPMENT OF COMPUTER TECHNOLOGY

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

In 1950, in Kiev, under the leadership of S. Lebedev, the Small Electronic Computer was created, which is referred to the first generation of electronic computers (computers). Its authors already at the Institute of Cybernetics in the development of the next generation of computers found that to calculate many problems, the universality of the computer is not necessary, it is enough to use a specialized electronic tool in which machine operations perform actions on more complex structures of numerical data. Thus, the most important problem of cybernetics in the field of computer creation was posed: the emergence of a contradiction between the growth of the hardware capabilities of the computer, and the use of a bit of binary arithmetic as a unit of processed information. This discovery was implemented in a specialized electronic counting machine. In the course of work on variants of internal mathematics of computers, an approach was found to overcome the contradiction by complicating the structure of the processed information by applying the apparatus of any numerical linear algebra which has a regular matrix representation as machine operands and corresponding machine operations. The chip implementation of such operands and operations on them made it possible to reduce their complexity and speed to the corresponding parameters of the hardware implementation of machine arithmetic. However, although the time to solve problems on such a machine was significantly reduced, the additional costs of software development were reduced, this approach was not used in the development of computers of subsequent generations, which did not allow to achieve higher performance indicators.

Modern technologies for the development of computer technology require a new internal mathematics in the computer, which would simplify the organization of calculations in it already at the level of nanotechnology. One of the search options can be the intellectual capabilities of a person, characterized by the unity of many levels of perception and processing of information.

IMMERSIVE INTERFACE MODULE

Y. Yakovliev, O. Yelisieieva
Glushkov Institute of Cybernetics NAS of Ukraine
yakyurlen@ukr.net, evo55555@ukr.net

Now the introduction of immersive technologies, which include augmented reality, virtual reality, mixed reality and artificial intelligence in educational processes to create immersive environments with a high degree of interactivity. Such environments require efficient immersive interfaces that allow users to gain in-depth experience in managing the learning environment.

An immersive interface module has been developed based on augmented reality technology, which is a modern solution to many problems related to providing additional visually-registered information about objects that surround or are in the field of self-perception. Augmented reality has opened up new ways in application development due to the peculiarities of interaction with the user and the environment. The module allows you to detect surfaces in the real world and interact with them, posting virtual content. The developed application analyzes the location of objects in space, calculates coordinates and tracks movement. The application of the module is relevant for training purposes, in the training of relevant specialists, in quests, exams, as well as in the study area, etc.

The main structural components of the module include: camera subsystem (access to preview from the camera and display on the smartphone screen, display of graphic objects above the connected previous cameras); subsystem for working with tracking and placement of 3D models (overlay selected 3D models on the reproduced image cameras, resize models, change their location); subsystem for storing geographical coordinates and records in the database (registration of the owner of the smartphone and saving photos, saving to a global database, etc.).

Using the module reduces the cost of equipment and the cost of unnecessary travel and location of objects, as well as the time of the procedure for the location of models is reduced by hundreds of times. It also has protection against unauthorized access and a user-friendly interface that does not require detailed study of the product for further operation. The developed application can be installed on a smartphone with the Android operating system, and using the camera of the device, place 3D models on the surface displayed on the screen. For the

development of the module were used: Android Studio, SQL, Java and JavaScript, PHP.

THE MIXTURE OF DISTRIBUTIONS AND THE INFLUENCE OF THE EXTERNAL ENVIRONMENT

O.A. Yarova, Ya.I. Yeleyko
Ivan Franko National University of Lviv, Ukraine
oksana.yarova@lnu.edu.ua

The states of the external environment are described using a homogeneous Markov chain $X(t)$ with discrete time $t=0, 1,..., n,...$ and a finite set of states $i=1, 2, ..., m$ with transition probabilities

$$p_{ij} = P\{X(1) = j \mid X(0) = i\}.$$

Let's construct an empirical distribution function. Denote

$$F_{em}^{j}(x) = \frac{\mu_i^j(x)}{n^j},$$

where $\mu_i^j(x)$ – number of sample elements $x_1^j(i),...,x_{n_j}^j(i)$.

Note that

$$\frac{n_j}{N} \to p_j.$$

Suppose that there are theoretical distribution functions $F_i^j(x)$, $j=1, 2,...,m$ for general groups $x_1^j(i),...,x_{n_j}^j(i)$, $j=1, 2,... ,m$.

According to the Kolmogorov criterion

$$F_{em(i)}^{j}(x) \to F_i^j(x).$$

So,

$$F_{em}^{j}(x) = \sum_{j=1}^{m} p_j \cdot F_i^j(x).$$

References

1. Skorokhod A.V. Lectures on the theory of random processes.: Study. manual. – L.: Lybid, 1990. – 168 p. (Ukraine)
2. Turchyn V.M. Mathematical statistics in examples and problems. – Kyiv: NMK VO, 1993. – 164 p. (Ukraine)

DETECTING CRITICAL NODES IN ADVERSARY NETWORKS USING PARTICLE SWARM OPTIMIZATION

Aygül Yeşim[1], Onur Uğurlu[2], Urfat Nuriyev[1,3]

[1]Ege University, Department of Mathematics, Izmir, Turkey

[2]Bakırçay University, Department of Fundamental Sciences, Izmir, Turkey

[3]Azerbaijan State Agricultural University, Ganja, Azerbaijan

yesimaygul7@gmail.com, onur.ugurlu@bakircay.edu.tr, urfat.nuriyev@ege.edu.tr

In network analysis, identifying the critical elements for the connectivity of a network is an essential task. Detecting these elements helps to analyze structural properties of networks such as attack tolerance, robustness, and vulnerability. Critical Node Problem (CNP) aims to find a set S consisting of at most k nodes, whose removal minimizes the connection between the node pairs in the remaining graph.

Identifying critical nodes can be used on telecommunication networks for both defensive and offensive approaches. From the offensive approach, critical nodes must be attacked to weaken communication in the adversary network. In military applications, it is vital to determine the attack points accurately since the resources for the attack are limited. Finding critical nodes in networks can help to detect these attack points.

In this study, we used the Particle Swarm Optimization algorithm for solving the CNP problem. We tested our solution approach on Krebs's terrorist network, which depicts the relationships between the terrorists constructed after the 9/11 attacks. The simulation results show that our algorithm could find optimal solutions for the CNP.

References

1. Lalou, M., Tahraoui, M. A., Kheddouci, H. (2018). The critical node detection problem in networks: A survey. *Computer Science Review, 28*, 92-117.

2. Walteros, J. L., Pardalos, P. M. (2012). Selected topics in critical element detection. *Applications of mathematics and informatics in military science*, 9-26.

COMPLEX OPTIMIZATION ALGORITHMS OF CONTROLLED PROCESSES

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

We build algorithms for complex optimization of complex controlled processes with concentrated and distributed parameters in interacting subsystems described by systems of differential equations and equations with partial derivatives. The difficulties of optimizing such systems are related both to the large dimensions of phase spaces in working models of controlled subsystems with partial derivatives and to the presence of nonlinear controlled subsystems. In the presence of nonlinear controlled subsystems, conjugate subsystems and the corresponding boundary value problems for coupled π-systems combined by maximizers of Hamiltonians on sets of admissible controls are significantly complicated. However, for linear controlled subsystems, the conjugated systems remain linear, and because of this, for linear (and often for quadratic) optimality criteria, the algorithms for calculating the optimal solutions of the corresponding subsystems are significantly simplified. Due to this, in the proposed algorithms of complex optimization, we use direct methods for optimization of linear subsystems, methods of linearization with reduction of systems with partial derivatives to systems of ordinary differential equations on adaptively optimized sets of nodes in admissible sets of phase spaces of subsystems, as well as methods of parametric local approximation of phase trajectories in around selected sampling points. In the case of using parametric polynomial approximations, algebraic subsystems of relationships between parameters appear, which significantly reduce the number of unknown parameters and the dimension of the corresponding parameter optimization problems in selected parametric classes of admissible control functions.

NOTE

_____
Підписано до друку 20.11.2022. Формат 60х84/16.
Папір офсетний. Гарнітура Таймс. Друк офсетний.
Ум. друк. арк. 7,55. Наклад 100. Зам. № 354.

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