Federal Research Center "Computer Science and Control" of Russian Academy of Science

The Montenegrin Academy of Sciences and Arts

University of Montenegro

University of Evora, Portugal

IX International Conference on Optimization Methods and Applications

OPTIMIZATION AND APPLICATIONS

(OPTIMA-2018)

Petrovac, Montenegro, October 2018

BOOK OF ABSTRACTS

Moscow — 2018

UDC 519.658

Book include abstracts of reports presented at the IX International Conference on Optimization Methods and Applications "Optimization and applications" (OPTIMA-2018) held in Petrovac, Montenegro, October 1 – October 5, 2018.
Edited by V.U. Malkova.

The Conference is organized by

The Montenegrin Academy of Sciences and Arts (MASA), Montenegro

University of Montenegro, Montenegro

University of Évora, CIMA-UE, Portugal

Dorodnicyn Computing Centre, FRC CSC RAS, Russia

Федеральный исследовательский центр
Информатика и Управление
Российской академии наук

Научное издание

Program Committee

Jaćimović Milojica, Chair, Montenegrin Academy of Sciences and Arts (Montenegro)
Evtushenko Yuri G., Chair, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Kalimoldayev Maksat, Chair, Institute of Information and Computational Technologies (Kazakhstan)

Adly Samir, University of Limoges (France)
Aida-Zade Kamil, Institute of Control Systems of ANAS, (Azerbaijan)
Afanasiev Alexander, Institute for Information Transmission Problems RAS (Russia)
Antipin Anatoly, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Balasundaram Baski, Oklahoma State University (USA)
Burdakov Oleg, Linkoping University (Sweden)
Butenko Sergiy, Texas A&M University (USA)
Bushenkov Vladimir, University of Evora (Portugal)
Bykadorov Igor, Sobolev Institute of Mathematics (Russia)
Druzhinina Olga, FRC CSC RAS (Russia)
Erzin Adil, Novosibirsk State University (Russia)
Facchinei Francisco, University of Rome La Sapienza (Italy)
Gasnikov Alexander, Moscow Institute of Physics and Technology (Russia)
Gornov Alexander, Inst. System Dynamics and Control Theory, SB RAS (Russia)
Ivanov Ivan, Sofia University (Bulgaria)
Jacimovic Vladimir, University of Montenegro (Montenegro)
Kaporin Igor, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Kelmanov Alexander, Sobolev Institute of Mathematics (Russia)
Khachay Mikhail, Krasovsky Institute of Mathematics and Mechanics (Russia)
Khamisov Oleg, L.A. Melentiev Energy Systems Institute (Russia)
Kovacevic-Vujcic Vera, University of Belgrade (Serbia)
Kochetov Yury, Sobolev Institute of Mathematics (Russia)
Krokhmal Pavlo A., University of Arizona (USA)
Kvasov Dmitri E., University of Calabria (Italy)

Lazarev Alexander, V.A. Trapeznikov Institute of Control Sciences (Russia)
Lotov Alexander, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Mijajlovic Nevena, University of Montenegro (Montenegro)
Nenad Mladenovic, Mathematical Institute, Serbian Academy of Sciences and Arts (Serbia)
Nedich Angelia, University of Illinois at Urbana Champaign (USA)
Nesterov Yuri, CORE Universite Catholique de Louvain (Belgium)
Olenev Nicholas, CEDIMES-Russie occ., Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Pardalos Panos, University of Florida (USA)
Pesterev Alexander, V.A. Trapeznikov Institute of Control Sciences (Russia)
Polyak Boris, V.A. Trapeznikov Institute of Control Sciences (Russia)
Popkov Yury, Institute for Systems Analysis, FRC CSC RAS (Russia)
Pospelov Igor, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Posypkin Mikhail, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Prokopyev Oleg, University of Pittsburgh (USA)
Bot Radu Ioan, University of Vienna (Austria)
Sergeyev Yaroslav, University of Calabria (Italy)
Sifaleras Angelo, University of Macedonia (Greece)
Shananin Alexander, Moscow Institute of Physics and Technology (Russia)
Staudigl Mathias, Maastricht University (Netherlands)
Thera Michel, University of Limoges (France)
Tchemisova Tatiana, University of Aveiro (Portugal)
Tatarczak Anna, Maria Curie Sklodowska University (Poland)
Tretyakov Alexey, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Uryasev Stan, University of Florida (USA)
Werner Frank, Otto-von-Guericke-University (Germany)
Will Adrian, National Technological University (Argentina)
Zhadan Vitaly, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Zhigljavsky Anatoly, Cardiff University (United Kingdom)
Zilinskas Julius, Vilnius University (Lithuania)
Zinder Yakov, University of Technology (Australia)

Zolotova Tatiana, Financial University under the Government of the Russian Federation (Russia)
Zubov Vladimir, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Zykina Anna, Omsk State Technical University (Russia)

Organizing Committee

Jaćimović Milojica, Chair, Montenegrin Academy of Sciences and Arts (Montenegro)
Evtushenko Yuri G., Chair, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Kalimoldayev Maksat, Chair, Institute of Information and Computational Technologies (Kazakhstan)
Posypkin Mikhail A., Chair, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)

Burova Natalia K., Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Golikov Alexander I., Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Gornov Alexander Yu.,Inst. System Dynamics and Control Theory, SB RAS (Russia)
Dragović Vesna, Montenegrin Academy of Sciences and Arts (Montenegro)
Jaćimović Vladimir, University of Montenegro (Montenegro)
Khachay Mikhail Yu., Krasovsky Institute of Mathematics and Mechanics (Russia)
Kelmanov Alexander V., Sobolev Institute of Mathematics (Russia)
Kochetov Yury A., Sobolev Institute of Mathematics (Russia)
Malkova Vlasta, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Mijajlović Nevena, University of Montenegro (Montenegro)
Obradovic Oleg, University of Montenegro (Montenegro)
Olenev Nicholas, Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Tchemisova Tatiana, University of Aveiro (Portugal)
Trusova Yulia O., Dorodnicyn Computing Centre, FRC CSC RAS (Russia)

Vladimirova Svetlana, Dorodnicyn Computing Centre,
FRC CSC RAS (Russia)
Zakharov Victor N., FRC "Computer Science and Control" RAS (Russia)
Zonn Ivetta A., Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Zubov Vladimir I., Dorodnicyn Computing Centre,
FRC CSC RAS (Russia)

Proceedings Chairs

Khachay Mikhail Yu., Krasovsky Institute of Mathematics and Mechanics (Russia)
Posypkin Mikhail A., Dorodnicyn Computing Centre, FRC CSC RAS (Russia)
Kochetov Yury A., Sobolev Institute of Mathematics (Russia)

Contents

Charged Balls Method. Construction. Convergence Analysis

Majid Abbasov[1]

[1] *St. Petersburg State University, SPbSU, 7/9 Universitetskaya nab., St. Petersburg, 199034 Russia;* m.abbasov@spbu.ru, abbasov.majid@gmail.com

Keywords: Charged Balls method, Computational geometry, Minimal distance.

Often for the construction of new optimization algorithms a transaction from an initial stationary problem to a some nonstationary mechanical system that tends to the position of equilibrium, which coincides with the solution of the problem, is used. Differential equations of the motion for this system give a continuous version of the method while the question of its convergence is equivalent to the question of the asymptotic stability of the corresponding equilibrium position. After using the difference scheme for solving the differential equations one receives an iterative algorithm.

The paper gives a detailed overview of the Charged Balls method. This is a new effective optimization method, that allows to solve some computational geometry problems. Questions of convergence and its rate are discussed. Numerical examples are provided.

The reported study was supported by Russian Science Foundation, research project 18-71-00006.

Synthesis of the Control of the Temperature Maintaining Process in a Heat Supply Problem

Vagif Abdullayev[1], **Kamil Aida-Zade**[2]

[1] *Azerbaijan State Oil and Industry University; Institute of Control Systems of Azerbaijan National Academy of Science, Azerbaijan;* vaqif_ab@rambler.ru

[2] *Baku State University; Institute of Control Systems, Azerbaijan National Academy of Sciences, Azerbaijan;* kamil_aydazade@rambler.ru

Keywords: optimal control, feedback, loaded differential equation

We consider a problem of controlling a heating appliance used for heating a heat-transfer agent, which delivers heat into a closed system. To control the process, we use feedback, under which information on the process state is continuously or discretely received from individual points of the appliance with installed temperature sensors. The mathematical model of the controlled process is described in both cases by a pointwise loaded first-order hyperbolic equation. We have obtained formulas for the gradient of the functional of the problem. These formulas allow us to use numerical first-order optimization methods for solving the problems.

Multiscale Modeling of Clusters of Point Defects in Semiconductor Structures

Karine Abgaryan[1], Ilya Mutigullin[2], Olga Volodina[3], Sergey Uvarov[4]

[1] *Dorodnicyn Computing Centre, FRC CSC RAS (Russia), Russia;*
kristal83@mail.ru

[2] *Dorodnicyn Computing Centre, FRC CSC RAS (Russia), Russia;*
mutigullin@gmail.com

[3] *Dorodnicyn Computing Centre, FRC CSC RAS (Russia), Russia;*
olga25v@gmail.com

[4] *Dorodnicyn Computing Centre, FRC CSC RAS (Russia), Russia;*
seruv25@gmail.com

Keywords: Multiscale modeling, point defects, high-performance software

Theoretical investigation of point defects formation processes in semiconductor structures is an important task aiming at improvement of the techniques of new materials design. Radiation exposure is one of the reasons of the formation of different types of defects such as point defects, extended and defect clusters in semiconductor structure. It was shown is a number of studies [1, 2] that after irradiation such structures obtain various properties that can be found useful for the construction of new generation nanolectronics devices. In this study multiscale approach [3] is applied to perform theoretical investigation of the defects forming in semiconductor structures due to irradiation. Because of the high complexity and versatility of the methods that are applied for computational modeling of defects in semiconductor materials a special software package for multiscale modeling of formation processes of point and extended defect clusters was developed.

Application of High-Performance Calculations for the Fitting of Interatomic Potentials

Karine Abgaryan[1], **Ilya Mutigullin**[2], **Olga Volodina**[3]

[1] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* kristal83@mail.ru
[2] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* mutigullin@gmail.com
[3] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* olga25v@gmail.com

Keywords: fitting, semiempirical potentials, molecular dynamics

In this study the fitting problem for a number of crystal structures and different potential types is solved. Simple pair potentials such as Morse potential and Lennard-Jones potential were chosen for the description of interatomic interaction in close-packed structures such as bulk W, Al, Fe, Cu, while much more complex Tersoff potential was chosen to describe interactions in wurtzite AlN crystal. For the construction of objective function values from ab initio calculations performed in the framework of density functional theory with the use of VASP package were used. It was shown that obtained sets of parameters allow us to describe bulk structures mentioned above and can be used for molecular dynamics studies of more complex structures. Because fitting problem is very consuming in terms of time and computational resources it is important to find the most effective methods for objective function minimization.

Approximate Solution of the Problem of Stabilization of Non-Linear Systems with Singular Matrix of Control Weight Coefficients

Alexander P. Afanas'ev[1], **Sergei M. Dzyuba**[2], **Elena V. Putilina**[3], **Irina I. Emelyanova**[4]

[1] *The Institute for Information Transmission Problems RAS, Russia;* apa@iitp.ru

[2] *TSTU, Russia;* sdzyuba@mail.ru

[3] *The Institute for Information Transmission Problems RAS, Russia;* elena@iitp.ru

[4] *TSTY, Russia;* Emelyanova-123@yandex.ru

Keywords: method of successive approximations, problem of stabilization of non-linear systems, singular matrix of control weight coefficients in the functional

Early works by these authors offer the method of successive approximations for developing the solutions of the problem of stabilization of non-linear systems with standard functional. This paper considers applying this method for studying the problem with singular matrix of control weight coefficients in the functional. It is demonstrated that this methods allows developing approximate smooth solutions of the initial problem. The work also investigates behaves successive approximations process in the neighborhood of the saturation point and states the relationship between this process and chattering regime initiation.

Three-Dimensional Visualization of Multidimensional Frontier Using Distributed Computations

Alexander Afanasiev[1], **Vladimir Krivonozhko**[2], **Andrey Lychev**[3], **Oleg Sukhoroslov**[4]

[1] *Institute for Information Transmission Problems RAS, Russia;* apa@ittp.ru

[2] *National University of Science and Technology MISiS, Russia;* KrivonozhkoVE@mail.ru

[3] *National University of Science and Technology MISiS, Russia;* lychev@misis.ru

[4] *Institute for Information Transmission Problems RAS, Russia;* sukhoroslov@iipt.ru

Keywords: data envelopment analysis, production frontier, multidimensional visualization

Data envelopment analysis (DEA) is extensively developed now and widely used for performance evaluation of decision making units. This approach is reduced to the solution of a large family of optimization problems. In this work we develop three-dimensional visualization of the multidimensional production possibility set with the help of constructions of three-dimensional sections using distributed computations. The visualization algorithms enable us to improve the frontier, reliably calculate important indicators of production units' behavior. Moreover, the visualization of multidimensional production possibility set is extremely important for decision making process. The suggested approach extends the ideas of related methods for reconstructing convex DEA frontiers proposed earlier by authors for the two-dimensional visualization. Our results are confirmed by computational experiments using real-life data sets.

Optimal Control by the System of Differential Equations of Block Structure with Blocks, Related by Boundary Conditions

Kamil Aida-Zade[1], **Yegana Ashrafova**[2]

[1] *Baku State University, Azerbaijan;* kamil_aydazade@rambler.ru
[2] *Baku State University, Institute of Control Systems of Azerbaijan National Academy of Sciences, Azerbaijan;* ashrafova.yegana@gmail.com

Keywords: optimal control, block structure, system of differential equations, nonlocal conditions, independent blocks, gradient of the functional

The solution to the problem of optimal control of a system of differential equations of a block structure is considered. The state of the process is described by a system of a large number of independent subsystems of linear non-autonomous differential equations. Blocks – subsystems of the general system are interconnected by nonlocal, unseparated boundary conditions. It is assumed that most of the elements of the bond matrix are zero, non-zero elements correspond to the presence of a connection between the initial and final states of individual blocks of a complex object. Necessary optimality conditions containing formulas for the gradient of the functional of the problem are obtained. These formulas allow using the first order optimization methods to solve the problems. The numerical experiments are carried out by using of suggested approach on the example of solving the test problems.

Optimization of Placing of Measurement Points and Membrane Vibrations Damper Points on Synthesis of Control by its Stabilization Modes

Kamil Aida-Zade[1], **Vugar Hashimov**[2]

[1] *Baku State University, Azerbaijan;* kamil_aydazade@rambler.ru
[2] *Institute of Control Systems of Azerbaijan National Academy of Sciences, Azerbaijan;* vugarhashimov@gmail.com

Keywords: optimal control, heating process, non-local conditions, synthesis of control, gradient of the functional, gradient projection method

The problem of extinguishing of vibrations of a thin elastic membrane fixed on border with given form is considered. Vibrations arise in result from simultaneous pulse impacts of external sources on some points of a membrane. Vibrations are calms due to control of the modes of pointwise dampers established in some points with use of information on the measurements received from measuring sensors. Process is described by a two dimensional PDE of hyperbolic type of the second order. The δ-function of Dirac, caused by pointwise indignation is participated in the equation. We suggest an approach on optimization of points of stabilizers location and control of a state of a membrane and control of the modes of calming of vibrations. The calming modes are defined by the linear combination of results of the current state of the membrane in measurement points. We use first order numerical methods for optimization of values of parameters of a feedback and points of measurement and stabilizers.

Optimization of Loading Places and Reaction Functions on them in Systems with Distributed Parameters

Kamil Aida-Zade[1], **Vagif Abdullayev**[2]

[1] *Baku State University; Institute of Control Systems of Azerbaijan National Academy of Science, Azerbaijan;* kamil_aydazade@rambler.ru

[2] *Azerbaijan State Oil and Industry University; Institute of Control Systems of Azerbaijan National Academy of Science, Azerbaijan;* vaqif_ab@rambler.ru

Keywords: optimal control, loaded differential equation, optimization of loading places, gradient of the functional

We consider a numerical solution to the problem of optimization of loading places and of corresponding reaction functions with respect to objects described by loaded partial differential equations. In these problems, it is required to restore (determine) the loading points and the functions of reaction on them from the available information on the observations of the process state. The choice of loading points and reaction functions under the condition of minimizing the functional of the root-mean-square deviation from the observed (desired) state values leads to the parametric optimal control problem. To solve the problem with the application of first-order numerical methods, we have derived analytical formulas for the gradient of the functional with respect to optimizable loading parameters. Numerical experiments have been carried out by the example of solving several test problems.

On the Stability of the Algorithm for Solving the Inverse Coefficient Problem for the Heat Equation

Alla Albu[1], **Vladimir Zubov**[2]

[1] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;*
alla.albu@yandex.ru

[2] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;*
vladimir.zubov@mail.ru

Keywords: inverse coefficient problems, heat equation, stability of algorithm

The inverse problem of determining the coefficient of the thermal conductivity of substance depending on the temperature is examined and investigated. The consideration is based on the first boundary value problem for the non-stationary heat equation. The mean-root-square deviation of the temperature distribution field and the heat flux from the experimental data on the boundary of the domain is used as the cost functional. An algorithm for the numerical solution of the problem based on the modern approach of Fast Automatic Differentiation is proposed. The numerical analysis of stability of the obtained solutions is carried out. It is shown that the perturbation of the recovered thermal conductivity coefficient is an order smaller than the perturbation of the experimental flux that caused it. In the case of perturbation of the experimental temperature field, the perturbation of the thermal conductivity coefficient is of the same order as the perturbation of the field itself.

On the Effectiveness of the Fast Automatic Differentiation Methodology

Alla Albu[1], **Andrei Gorchakov**[2], **Vladimir Zubov**[3]

[1] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;*
alla.albu@yandex.ru

[2] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;*
andrgor12@gmail.com

[3] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;*
vladimir.zubov@mail.ru

Keywords: Fast Automatic Differentiation, standard software packages, Tersoff potential

In this work we compare the approaches for calculating the gradient of a complex function of many variables using the Fast Automatic Differentiation methodology, standard software packages and formulas obtained analytically. Based on the example of a complex function that represents the energy of atoms' system whose interaction potential is the Tersoff potential, the computer time required to calculate the gradient of the function is estimated. The results obtained in this work showed the superiority of the use of Fast Automatic Differentiation methodology and standard software packages.

Analysis of Indicators of High-Technology Production Using Optimization Models, Taking into Account the Shortage of Working Capital

Damir Alimov[1], **Nataliia Obrosova**[2], **Alexander Shananin**[3]

[1] *Lomonosov Moscow State University, Russia;* alimov2007d@gmail.com

[2] *Dorodnicyn Computing Centre of FRC CSC RAS, Russia;* nobrosova@yandex.ru

[3] *Mosow Institute of Physics and Tehnology (State University), Russia;* alexshan@yandex.ru

Keywords: Bellman equation, production model, unstable demand, current assets deficit, debt burden, identification, capitalization

We present a new approach to estimate of company's value in the high-tech sector, based on the results of research of the mathematical model of production, taking into account the crediting of working capital in an unstable demand. The model has the form of Bellman equation. The solution gives an estimate of the enterprize value depending on its performance indicators and external economic conditions. The method develops the income approach to estimate of company's value and takes into account the specifics of the economic regulation of production in the industry and provides an opportunity for an operative analysis of production indicators when external conditions change. The paper presents the results of capitalization analysis of Kamaz company in terms of the model. The results of research of model modification that takes into account the impact of the accumulated debt burden on the company's are presented.

On Stabilization Problem for a Loaded Heat Equation: the Two-Dimensional Case

Meiramkul Amangaliyeva[1], Muvasharkhan Jenaliyev[2], Assem Ayazbayeva[3], Kanzharbek Imanberdiyev[4]

[1] *Institute of Mathematics and Mathematical Modeling, Kazakhstan;* jenalika@gmail.com

[2] *Institute of Mathematics and Mathematical Modeling, Kazakhstan;* muvasharkhan@gmail.com

[3] *Al-Farabi Kazakh National University, Kazakhstan;* aayazbayeva@gmail.com

[4] *Al-Farabi Kazakh National University, Kazakhstan;* Kanzharbek75ikb@gmail.com

Keywords: boundary stabilization, heat equation, loaded Laplace operator

The stabilization problem (of forming a cylinder) of a solution of boundary value problem for heat equation with the loaded two-dimensional Laplace operator is considered. An algorithm is proposed for approximate construction of boundary controls providing the required stabilization of the solution. The work continues the research of the authors carried out earlier for the loaded one-dimensional heat equation. The idea of reducing the stabilization problem for a parabolic equation by means of boundary controls to the solution of an auxiliary boundary value problem in the extended domain of independent variables belongs to A.V. Fursikov. At the same time, recently, the so-called loaded differential equations are actively used in problems of mathematical modeling and control of nonlocal dynamical systems.

Group Solution of the Classification Problem on the Basis of Compact Groups

Yedilkhan Amirgaliyev[1], Lyaillya Cherikbayeva[2], Didar Yedilkhan[3], Bekturgan Kalybek Uuly[4]

[1] *Institute of Information and Computational Technologies, Kazakhstan;* amir_ed@mail.ru

[2] *Al-Farabi Kazakh National University, Kazakhstan;* lyailya_sh@mail.ru

[3] *International Information Technology University, Kazakhstan;* yedilkhan@gmail.com

[4] *Institute of Automation and Information Technologies, Kyrgyzstan;* bekturgan@gmail.com

Keywords: Pattern recognition, functional quality, group synthesis

The main task of the group synthesis of algorithms of classification is to construct the optimal partitioning of the result of the test object in a plurality of sets of partitions generated by each algorithm, a basic set of components of the group. The notion of optimality is specified for the specific tasks of recognition and classification, using a variety of criteria (functional) quality [1-2]. We formulate the problem of group synthesis. Given a set of object classification . Each object t is uniquely described by a set of numerical parameters, called attributes of characterizing objects. Thus, a subset of n-dimensional space. There are many – a set of classification algorithms, forming a group.

According to the principle of operation of the algorithms from, each subset consists of objects defined as central objects using the algorithms.

The algorithm is implemented and tested in solving real-world problems [3].

Calculation of the Solar Heating System of a Residential Building

Yedilkhan Amirgaliyev[1], Murat Kunelbayev[2], Aliya Kalizhanova[3], Didar Yedilkhan[4], Omirlan Auelbekov[5], Nazbek Kataev[6], Ainur Kozbakova[7]

[1] *Institute Information and Computational Technologies CS MES RK, Kazakhstan;* amir_ed@mail.ru

[2] *Institute Information and Computational Technologies CS MES RK, Kazakhstan;* murat7508@yandex.kz

[3] *Institute Information and Computational Technologies CS MES RK, Kazakhstan;* kalizhanova_aliya@mail.ru

[4] *Institute Information and Computational Technologies CS MES RK, Kazakhstan;* yedilkhan@gmail.com

[5] *Institute Information and Computational Technologies CS MES RK, Kazakhstan;* omirlan@mail.ru

[6] *Institute Information and Computational Technologies CS MES RK, Kazakhstan;* k_nazbek@mail.ru

[7] *Institute Information and Computational Technologies CS MES RK, Kazakhstan;* ainur79@mail.ru

Keywords: Flat solar collector, Accumulator tank, Power, Heat carrier temperature

In this article we will consider the calculation of the solar system for the heat supply of an apartment house. To calculate the solar heating system of a residential house, we use circuits with forced circulation in the solar circuit. Calculation of the heat balance of the house is performed using increased indicators to calculate heat losses. The parameters of the solar collector for heating the residential building during the period 2017-2018 are calculated. Dependencies of the water temperature on the solar collector and reservoir storage are constructed, as well as the dependencies as a percentage of the power as a function of time.

Analytical Methods for Solving Linear Game Models with Different Dynamics

Saltanat Amirgaliyeva[1], **Olga Ostapenko**[2], **Didar Yedilkhan**[3]

[1] *Institute of Information and Computational Technologies, Kazakhstan;*
saltanat_amirgal@mail.ru

[2] *V.M.Glushkov Institute of Cybernetics, Ukraine;*
olga.ostapenko@tns-ua.com

[3] *Institute of Information and Computational Technologies, Kazakhstan;*
yedilkhan@gmail.com

Keywords: Differential games, terminal set, terminal functional, matrix convexity, strategy, players

This research proposed analytical methods for solving linear differential games that allow to build sufficiently constructive strategy players. Methods of application of the notion of matrix convexity, while building the optimal strategies of players in linear game models with terminal sets, terminal functional, and different dynamics are shown.

The Application of the Methodology of Fast Automatic Differentiation to Calculate the Gradient of the Potential REBO (LAMMPS)

Gulshat Amirkhanova[1], Andrei Gorchakov[2], Aigerim Duysenbaeva[3]

[1] *Institute for Information and Computing Technologies, Almaty, Kazakhstan;*
gulshat.aa@gmail.com

[2] *Dorodnicyn Computing Centre of FRC CSC RAS, Russia;*
andrgor12@gmail.com

[3] *Institute for Information and Computing Technologies, Almaty, Kazakhstan;*
aigerim.95.05@mail.ru

Keywords: fast automatic differentiation, two-dimensional crystals, REBO potential, LAMMPS

In this paper we consider the problem of finding the energy minimum of the aggregate of atoms of a fragment of a planar crystal lattice. To calculate the energy, the Brennor or REBO (reactive empirical bond order) method is used. The REBO potential is calculated using the LAMMPS package (Large-scale Atomic / Molecular Massively Parallel Simulator). As optimization methods, both the gradientless methods and the methods using the first derivatives of the functional are used. To calculate the derivatives, the combined differentiation method, implemented in the LAMMPS package, is used, using sequentially forward and reverse methods of fast automatic differentiation.

GPU-Accelerated Algorithms for Morse Potential Energy Minimization

Anton Anikin[1], **Aleksander Gornov**[2], **Alexander Andrianov**[3]

[1] *Matrosov Institute for System Dynamics and Control Theory of SB RAS, Russia;* anton.anikin@htower.ru

[2] *Matrosov Institute for System Dynamics and Control Theory of SB RAS, Russia;* gornov.a.yu@gmail.com

[3] *Keldysh Institute of Applied Mathematics RAS, Russia;* and@a5.kiam.ru

Keywords: Global optimization, Morse potential, GPU, parallel computing

The paper presents results of numerical study of Morse potential optimization problem, which has a high complexity due to the huge number of local minimums. The paper is devoted to the applying of computational facilities of modern graphics accelerators (GPU) for finding solution of the considered problem. We presents some of global and local optimization algorithms implemented for running on GPUs. We discuss modified version of well-known "Monotonic Sequential Basin Hopping" (MSBH) and also author's "Forest" global algorithms. We also discuss the properties and performance of modified versions of local optimization algorithms which can be efficiently implemented for modern GPUs (Nvidia Pascal architecture). Number of computational techniques for increasing algorithms performance are investigated. Results of numerical experiments and putative global minimums for Morse clusters with atoms count 240-270 are presented.

Recurrent Algorithm for Scenario Lattice Construction

Evgeny Antonov[1], **Dmitry Golembiovsky**[2], **Dmitry Denisov**[3]

[1] *Moscow State University, Russia;* eugeneP.antonov@gmail.com
[2] *Moscow State University, Russia;* golemb@cs.msu.su
[3] *Moscow State University, Russia;* dvden@bk.ru

Keywords: non-convex problem, linear programming, stability, admissibility, optimal solution, scenario lattice

The report represents the extension of the paper of Dmitry Golembiovsky, Dmitry Denisov, Evgeny Antonov "On solving the problem of optimal probability distribution quantization" (2010), published in CEUR Workshop Proceedings, M. Jeusfeld c/o Redaktion Sun SITE, Informatik V, RWTH Aachen (Aachen, Germany), 1987 (8), 217-223. A new method of a problem of scenario lattice constructing for SDDP algorithm is suggested. The method is based on consecutive update of vector of parameters of objective function with bilinear constraints. Updated parameters have a significant dimensionality, their calculation is based on the result of the solution of other variables, for which constraints functions are linear. Thus, the method allows to reduce the initial problem to a sequence of linear problems. Results of numerical experiments of lattice construction are examined.

New Task Domain Propagators with Polynomial Complexity for Resource-Constrained Project Scheduling Problem

Dmitry Arkhipov[1], **Olga Battaia**[2], **Alexander Lazarev**[3], **German Tarasov**[4], **Ilia Tarasov**[5]

[1] *V. A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, Russia;* miptrafter@gmail.com

[2] *ISAE-SUPAERO, France;* olga.battaia@isae.fr

[3] *V. A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, Russia;* jobmath@mail.ru

[4] *V.A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, Russia;* gv.tarasov@physics.msu.ru

[5] *V. A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, Russia;* ia.tarasoff@gmail.com

Keywords: Project scheduling, Constrained programming, Scheduling, RCPSP, Task domain propagators

We consider a classic Resource-Constrained Project Scheduling (RCPSP) problem which is known to be NP-hard. For defined project deadline T, each task of the project can be associated with its temporal domain - a time interval in which this task can be processed. In this research, we present new polynomial-time algorithms (propagators) used to tighten such temporal task domains in order to make the optimization problem easier to solve. Numerical experiments show the efficiency of developed propagators in preprocessing for improving the performances of existing solution methods for RCPSP. Moreover, we show how these propagators can be used for calculating an efficient lower bound on project makespan.

p-Factor Approach for Solving Nonregular Mathematical Programming Problems

Ewa Bednarczuk[1], **Agnieszka Prusińska**[2], **Alexey Tretyakov**[3]

[1] *System Research Institute Polish Academy of Sciences, Poland;* Ewa.Bednarczuk@ibspan.waw.pl

[2] *Siedlce University, Faculty of Science, Poland;* aprus@uph.edu.pl

[3] *Dorodnitsyn Computing Center FRC CSC, Russian Academy of Sciences, Russia;* tret@uph.edu.pl

Keywords: nonlinear programming, inequality constraints, p-regularity, nonregularity, singularity

We consider the nonlinear programming problem (NLP) with inequality constraints

$$\min \varphi(x) \;\; \text{subject to} \;\; g_1(x) \geq 0, \ldots, g_m(x) \geq 0,$$

where φ and g_i, $i = 1, \ldots, m$ are smooth functions from R^n to R.

There are various methods for solving the NLP, which are based on the Karush-Kuhn-Tucker (KKT) conditions of optimality. However, this approach usually require some regularity constraints qualifications (RCC), second-order sufficient conditions (SOSC) and strict complementarity conditions (SCC). We propose the method which can be used when some of the conditions, KKT, RCQ, SOSC, RCC fails, that is when the problem is nonregular.

Solutions of Traveling Wave Type for Korteweg-de Vries-Type System with Polynomial Potential

Armen Beklaryan[1], **Leva Beklaryan**[2], **Alexander Gornov**[3]

[1] *National Research University Higher School of Economics, Russia;* abeklaryan@hse.ru

[2] *Central Economics and Mathematics Institute RAS, Russia;* lbeklaryan@outlook.com

[3] *Matrosov Institute for System Dynamics and Control Theory of SB RAS, Russia;* gornov@icc.ru

Keywords: traveling waves, Kortewegde Vries equation, functional differential equations

This paper deals with the implementation of numerical methods for searching for traveling waves for Kortewegde Vries-type equations with time delay. Based upon the group approach, the existence of traveling wave solution and its boundedness are shown for some values of parameters. Meanwhile, solutions constructed with the help of the proposed constructive method essentially extend the class of systems, possessing solutions of this type, guaranteed by theory. The proposed method for finding solutions is based on solving a multiparameter extremal problem. Several numerical solutions are demonstrated.

Optimization on the Symplectic Group and Applications

Petre Birtea[1], **Ioan Casu**[2], **Dan Comanescu**[3]

[1] *West University of Timisoara, Romania;* petre.birtea@e-uvt.ro
[2] *West University of Timisoara, Romania;* ioan.casu@e-uvt.ro
[3] *West University of Timisoara, Romania;* dan.comanescu@e-uvt.ro

Keywords: optimization, symplectic group, constraint manifold, numerical algorithms, least-square problem

By embedding the real symplectic group $Sp(2n)$ in an ambient Euclidean space, we construct the gradient embedded vector field. We present necessary and sufficient conditions for critical points of a cost function. We further give an explicit formula for the Hessian operator on the symplectic group written in the ambient coordinates. As an application, we explicitly describe the steepest descent and Newton algorithms on $Sp(2n)$ for the least-square and generalized Brockett cost functions.

Shape Preserving Conditions under Interpolation by Parabolic Splines

Vladimir Bogdanov[1], **Yuriy Volkov**[2]

[1] *Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences, Russia;* bogdanov@math.nsc.ru

[2] *Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences, Russia;* volkov@math.nsc.ru

Keywords: parabolic spline, interpolation, shape preserving

Parabolic splines are applied to solve an interpolation problem with the conditions of preserving the piecewise monotonicity and convexity. Sufficient conditions are established for the piecewise monotonicity and convexity of Subbotin's quadratic interpolation splines, and numerical examples are given.

A General Double-Proximal Gradient Algorithm for D.C. Programming

Radu Ioan Bot[1]

[1] *University of Vienna, Austria;* radu.bot@univie.ac.at

Keywords: dc programming, Toland dual, proximal-gradient algorithm, KurdykaLojasiewicz property

The possibilities of exploiting the special structure of d.c. programs, which consist of optimizing the difference of convex functions, are currently more or less limited to variants of the DCA methods. These assume that either the convex or the concave part, or both, are evaluated by one of their subgradients.

In this talk we propose an algorithm which allows the evaluation of both the concave and the convex part by their proximal points. Additionally, we allow a smooth part, which is evaluated via its gradient.

For this algorithm we show that every cluster point is a solution of the optimization problem. Furthermore, we show the connection to the Toland dual problem and prove a descent property for the objective function values of a primal-dual formulation of the problem. Convergence of the iterates is shown if this objective function satisfies the Kurdyka - Lojasiewicz property. In the last part, we apply the algorithm to an image processing model.

The Method of Non-local Control Improvement in Optimal Control Problems with Constraints

A.S. Buldaev[1], **I.D. Burlakov**[2]

[1] *Buryat State University, Russia;* buldaev@mail.ru
[2] *Buryat State University, Russia;* ivan.burlakov.91@mail.ru

Keywords: controlled system with constraints, conditions for improving control, fixed point problem

A new approach to solving optimal control problems with terminal and phase constraints is proposed on the basis of constructing and solving a system of conditions for improving admissible control in the form of the fixed point problem for a constructed control operator. This form makes it possible to apply the developed theory and fixed-point methods for the effective search of admissible improving controls. To construct these conditions, we apply the transition to the auxiliary problem of optimizing a regular Lagrange functional without constraints with mixed control functions and parameters. Approbation and comparative analysis of the effectiveness of the proposed approach of fixed points on model and test examples is carried out

Limited Memory Methods with a Search over a Model-Based Steepest Descent Path

Oleg Burdakov[1], **Serge Gratton**[2]

[1] *Linkoping University, Linkoping, Sweden;* oleg.burdakov@liu.se
[2] *ENSEEIHT-IRIT, Toulouse, France;* serge.gratton@enseeiht.fr

Keywords: limited memory quasi-Newton methods, trust region method, cubic regularization method

Limited memory quasi-Newton methods are among the most powerful tools used for solving large scale optimization problems. A compact representation of limited memory quasi-Newton updates allows for obtaining in a cheap way an implicit spectral decomposition of the Hessian approximation. We exploit this decomposition for finding the steepest descent path that is the solution of the ordinary differential equation whose right-hand side equals the minus gradient of the quadratic model based on the Hessian approximation. We show how to use this path for finding approximate solution of subproblem related to the trust region as well as cubic regularization globalization strategies. To the best of our knowledge, there was no attempt to combine limited memory methods with cubic regularization techniques. Their straightforward combination is prohibitively too expensive. Our numerical experiments indicate that our algorithms are competing with the existing limited memory quasi-Newton algorithms.

Dynamic Marketing Model: Optimization of Retailer's Role

Igor Bykadorov[1]

[1] *Sobolev Institute of Mathematics SB RAS, NSU, NSUEM, Russia;*
bykadorov.igor@mail.ru

Keywords: Retailer, Pricing, Pass-Through, Sale Motivation

We study a vertical control distribution channel in which a manufacturer sells a single kind of good to a retailer. The state variables are the cumulative sales and the retailer's motivation. The manufacturer chooses wholesale price discount while retailer chooses pass-through. We assume that wholesale price discount increases the retailer's sale motivation thus improving sales. In contrast to previous settings, we focus on the maximization of retailer's profit with respect to pass-through. The arising problem is linear with respect to both cumulative sales and the retailer's motivation, while it is quadratic with respect to wholesale price discount and pass-through. We obtain a complete description of optimal strategies and optimal trajectories. In particular, we demonstrate that the number of switches for change in the type of the optimal policy is no more than one.

Retailing under Piece-Wise Constant Pricing

Igor Bykadorov[1]

[1] *Sobolev Institute of Mathematics SB RAS, NSU, NSUEM, Russia;*
bykadorov.igor@mail.ru

Keywords: Piece-Wise Sale Prices, Retailer, Pass-Through, Concavity

We study a trade model in "consumer - retailer - manufacturer" structure. In classical set-ting, the arising problem is linear with respect to the cumulative sales and the retailer's motivation, while it is quadratic with respect to wholesale price discount and pass-through. Thus, the optimal sale price is continuous; this seems not adequate from economical point of view. In contrast, we assume that the wholesale price is constant while the sale price is piece-wise constant with fixed switch moments. This way the model reduces to the quadratic programming problem where the variables are the pass-through levels. We obtain the structure of optimal sale policy and show that, for any fixed switches, the profit of retailer is con-cave function with respect to pass-through levels.

Sufficient Conditions for Polynomial Solvability of the Two-Machine Preemptive Routing Open Shop on a Tree

Ilya Chernykh[1]

[1] *Sobolev Institute of Mathematics, Novosibirsk, Russia;* idchern@gmail.com

Keywords: Routing open shop, Preemption, Tree-like transportation network, Polynomially solvable subclass, Overloaded nodes, Overloaded edges

The routing open shop problem with preemption allowed is a natural combination of the metric TSP problem and the classical preemptive open shop scheduling problem. While metric TSP is strongly NP-hard, preemptive open shop is polynomially solvable for any (even unbounded) number of machines. The previous research on the preemptive routing open shop is mostly focused on the case with just two nodes of transportation network. It is known to be strongly NP-hard in the case of unbounded number of machines and polynomially solvable for the two-machine case. The algorithmic complexity of both two-machine problem on a triangular network and three-machine problem with two nodes are still unknown. The problem with a general transportation network is a generalization of the metric TSP and therefore is strongly NP-hard.

We describe a wide polynomially solvable subclass of the preemptive routing open shop on a tree. This class allows building optimal schedule with at most one preemption.

Swarms on Spheres for Unsupervised Learning

Aladin Crnkić[1], **Vladimir Jaćimovič**[2]

[1] *Faculty of Technical Engineering, University of Bihać, Bosnia and Herzegovina;* aladin.crnkic@hotmail.com

[2] *Faculty of Natural Sciences and Mathematics, University of Montenegro, Montenegro;* vladimir@jacimovic.me

Keywords: multi-agent system, consensus, community detection, data clustering

We propose a new class of algorithms for data mining that are based on consensus and synchronization in multi-agent systems on spheres S^n. This approach is applied to some important problems in Machine learning, including clusterization of data in R^k, community detection in complex networks, etc.

The method can be adapted to some problems with high computational complexity, such as clusterization of multivariate functional data. The presentation is concluded by the discussion and evaluation of results obtained for some benchmark data sets.

An Effective Heuristic for the l1-Metric $(r|p)$-Centroid Problem

Ivan Davydov[1], **Yury Kochetov**[2]

[1] *Sobolev Institute of Mathematics, Russia;* Vann.davydov@gmail.com
[2] *Sobolev Institute of Mathematics, Russia;* jkochet@math.nsc.ru

Keywords: bi-level, mathematical programming, metaheuristic

We consider the l1-metric $(r|p)$-centroid problem. In this bi-level facility location problem, two players, the leader and the follower, consecutively open facilities to service clients. Clients are located on the 2-dimensional plane, and facilities can be opened at any point. The leader opens p facilities. Later on, the follower opens r facilities. Each client patronizes the closest facility according to the l1 metric. In case of ties, the leader's facilities are preferred. The goal is to find the location of p facilities for the leader to maximize her market share. We suggest a discretization procedure which allows relocating optimally one facility of the leader. Based on this approach we propose an effective heuristic to tackle the problem. The results of the numerical experiments carried out on instances from the benchmark library "Discrete Location Problems" and comparison with the l2 solutions are provided.

This research was supported by RFH grant 16-02-00049.

Optimal Control of Train on Uneven Surface Profile

Vasily Dikusar[1], **Andrzej Yatsko**[2]

[1] *MIPT, Russia;* dikussar@yandex.ru

[2] *Koszalin University of Technology, Poland;* andrzej.jacko@gmail.com

Keywords: Dibovitsky-Milyutin scheme, nonlinear programming, parallel computations, processing of information, stiff systems, factor analysis

Two optimal problems for movement train with accounting profile of path are considered. There are minimum energetic inputs; minimum time problem. Maximum speed is constrained (state constraint). A two-stage method of solution optimal control problem is suggested. On the first stage, we solve a discrete problem with using improper nonlinear programming to result geometry of optimal path. The second stage is connected with verification of the discrete solution on the base Dibovitsky-Milyutin scheme. Methods of continuation the solution, parallel calculations and information processing are used.

The Synthesis of the Switching Systems Optimal Parameters Search Algorithms

Olga Druzhinina[1], **Olga Masina**[2], **Alexey Petrov**[3]

[1] *Federal Research Center "Computer Science and Control" of Russian Academy of Sciences, Russia;* ovdruzh@mail.ru

[2] *Bunin Yelets State University, Russia;* olga121@inbox.ru

[3] *Bunin Yelets State University, Russia;* xeal91@yandex.ru

Keywords: dynamical switching model, optimal parameters of motion, optimal control, algorithms, computational experiment, articial neural networks

The problems of the optimal motion parameters search for generalized models of the dynamical systems are considered. The switch ing dynamic models taking into account action of non-stationery forces and optimality conditions are studied. The method for designing of the dynamical models using polynomial regression is proposed. The optimal analytical solutions for some types of the parametric curves are found. The algorithms of the optimal motion parameters search by means of the intelligent control methods are elaborated. The indicated algorithms and the software package allowed to execute a series of computational experiments and to carry out the stability analysis. The prospects of the results development in terms of generalization and modification of the models and the methods are presented. The results and the algorithms can be applied to the problems of automated transport design, robotics and aircrafts motion control.

Centralized Distributed Optimization for Wasserstein Barycenters

Darina Dvinskikh[1], **Alexander Gasnikov**[2], **Pavel Dvurechensky**[3], **Alexey Kroshnin**[4], **Cesar A. Uribe**[5], **Angelia Nedich**[6]

[1] *Moscow Institute of Physics and Technology, Russia;* dviny.d@yandex.ru
[2] *Moscow Institute of Physics and Technology, Russia;* gasnikov@yandex.ru
[3] *Weierstrass Institute for Applied Analysis and Stochastics, Germany;* pavel.dvurechensky@gmail.com
[4] *Moscow Institute of Physics and Technology, Russia;* kroshnin@phystech.edu
[5] *University of Illinois at Urbana-Champaign, United States;* cauribe2@illinois.edu
[6] *Arizona State University, United States;* angelia.nedich@asu.edu

Keywords: Convex optimization, first-order methods, optimal transport, distributed optimization

Wasserstein barycenter problem is a sphere of active research and application of distributed and parallel optimization due to its challenging computations involving multiple calculations of Wasserstein distance which is linear program. We propose a centralized distributed method of computing the Wassertein barycenter of entropic regularized Wasserstein distances of a set of discrete approximations of probability measures. We analyze three algorithms, Bregman iterative projection [J.D. Benamou et al., SIAM, 2015], parallel algorithm from [M. Cuturi et al., SIAM, 2016], accelerated distributed gradient method [P. Dvurechensky et al., arXiv:1806.03915, 2018], and compare them with proposed method in terms of the problem parameters and the desired accuracy of the solution.

A Stable Alternative to Sinkhorns Algorithm for Regularized Optimal Transport

Pavel Dvurechensky[1], Alexander Gasnikov[2], Sergey Omelchenko[3], Alexander Tiurin[4]

[1] *Weierstrass Institute for Applied Analysis and Stochastics, Germany;*
pavel.dvurechensky@gmail.com

[2] *Moscow Institute of Physics and Technology (State University), Russia;*
gasnikov.av@mipt.ru

[3] *Moscow Institute of Physics and Technology (State University), Russia;*
sergey.omelchenko@phystech.edu

[4] *National Research University Higher School of Economics, Russia;*
alexandertiurin@gmail.com

Keywords: smooth convex optimization, linear constraints, first-order methods, accelerated gradient descent, primal-dual method, Sinkhorns algorithm

In this work, we are motivated by two important applications: entropy-regularized optimal transport problem and road or IP traffic demand matrix estimation by entropy model. Both of them include solving a special type of optimization problem with linear equality constraints and objective given as a sum of an entropy regularizer and a linear function. We consider the above optimization problem as a particular instance of a general strongly convex optimization problem with linear constraints. We propose a new algorithm to solve this general class of problems and prove the rate $O(1/k^2)$, k being the iteration counter, both for the absolute value of the primal objective residual and constraints infeasibility. We illustrate the advantage of our method by numerical experiments for the two mentioned applications.

Isolation of the Trivial Part of a Nonlinear Control System

Vladimir Elkin[1]

[1] *Institution of Russian Academy of Sciences Dorodnicyn Computing Centre of RAS, Russia;* elk_v@mail.ru

Keywords: Nonlinear control systems, Aggregated systems, Decomposition, Factorization

The problem of constructing aggregated systems (quotient systems) of the simplest kind for nonlinear control systems is considered. With the help of this factorization, the original control system is reduced to a decomposition that allows one to reduce the dimension of control problems.

On Complexity and Exact Solution of Production Groups Formation Problem

Anton Eremeev[1], **Igor Ziegler**[2], **Alexander Kononov**[3]

[1] *Omsk Branch of Sobolev Institute of Mathematics SB RAS, Russia;* eremeevtmp@yandex.ru

[2] *Sobolev Institute of Mathematics, Omsk Branch, Russia;* ziegler.igor@gmail.com

[3] *Sobolev Institute of Mathematics, Russia;* alvenko@math.nsc.ru

Keywords: integer programming, optimization on graphs, production groups, branch and bound algorithm

Success of a modern enterprize is substantially determined by the effectiveness of staff selection and formation of various kinds of functional groups. Creation of such groups requires consideration of different factors depending on the activity of the groups. The problem of production groups formation, considered in this paper, asks for an assignment of workers to jobs taking into account the implicational constraints. The first result of the paper states the NP-hardness of the problem under consideration. The second result is a branch and bound method, which uses supplementary assignment problems for computing bounds. A software implementation of the algorithm is made, and a computational experiment is carried out, comparing the proposed algorithm with the CPLEX solver on randomly generated input data.

New Perspective on Some Classical Results in Optimization

Yuri Evtushenko[1], **Alexey Tretyakov**[2], **Vlasta Malkova**[3]

[1] *Dorodnicyn Computing Centre, FRC CSC, Russia;* yuri-evtushenko@yandex.ru

[2] *Dorodnicyn Computing Centre, FRC CSC, Russia;* tret@uph.edu.pl

[3] *Dorodnicyn Computing Centre, FRC CSC, Russia;* vmalkova@yandex.ru

Keywords: optimization, necessary conditions, Newton methods, p-regularity

We present an elementary proof of the Lagrange multiplier theorem for optimization problems with equality constraints, Kuhn-Tucker theorem for optimization problems with inequality constraints and another one in classical optimization theory. Most proofs in literature rely on advanced concepts and results such as implicit functional theorem, Lusternic theorem, Farkas theorem and others. By contrasts the proofs given in our article employ only basic results from linear algebra, the critical-point condition for unconstrained minima, and the fact that a continuous function attains its minimum over a closed ball.

Systems of Linear Equations and/or Inequalities, Duality and Unconstrained Optimization

Yuri Evtushenko[1], **Alexander I. Golikov**[2]

[1] *Dorodnicyn Computing Centre, FRC CSC RAS, Moscow, Russia, Russia;* evt@ccas.ru

[2] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* gol-a@yandex.ru

Keywords: systems of linear equations and/or inequalities, regularization, projection of a point, duality, Newtons method, unconstrained optimization

The problems of finding a solutions to an underdetermined systems of linear equations with nonnegative variables and systems of linear inequalities do not belong to the classical problems of computational linear algebra. Typically, these tasks have an nonunique solution. They can be reduced to optimization problems. To solve such problems, it is useful to utilize the duality theory and various optimization methods, e.g., Newton's method. Optimization methods make it possible to select a single solution from a solution set of a linear system (for example, the normal solution, the projection of a given point). The initial system with m equations/inequalities and n variables is reduced to the unconstrained minimization problem with the number of variables equaling to min(m, n). The results of numerical experiments for solving large linear systems using MATLAB are presented.

Optimal Control of Convex Differential Inclusion

Alexander Fominyh[1]

[1] *Saint-Petersburg State University, Russia;* alexfomster@mail.ru

Keywords: differential inclusion, Gateaux gradient, the steepest descent method

We study a differential inclusion with a given continuous convex multivalued mapping. For a given finite time interval, it is required to construct a solution of the differential inclusion, that satisfies the given initial and the final conditions and minimizes the integral functional. With the help of support functions, the original problem is reduced to minimizing some functional in the space of piecewise continuous functions. In the case of continuous differentiability of the support function of a multivalued mapping with respect to the phase variables, this functional is Gateaux differentiable. In the report, Gateaux gradient is found, necessary conditions for the minimum of the given functional are obtained. On the basis of these conditions, the method of the steepest descent is applied to the original problem. Numerical examples illustrate the constructed algorithm realization.

Constructive Heuristic with Guaranteed Bounds (CHwGB)

Damir Gainanov[1], **Nenad Mladenovic**[2], **Varvara Rasskazova**[3], **Dragan Urosevic**[4]

[1] *Ural Federal University, Russia;* damir.gainanov@gmail.com
[2] *Serbian Academy of Sciences and Arts, Serbia;*
nenadmladenovic12@gmail.com
[3] *Moscow Aviation Institute, Russia;* varvara.rasskazova@mail.ru
[4] *Serbian Academy of Sciences and Arts, Serbia;*
draganu@turing.mi.sanu.ac.rs

Keywords: Graph Optimization, Constructive Heuristic, Guaranteed Bound, Maximum Clique Problem, Traveling Salesman Problem

Constructive heuristics are usually used for finding an initial solution of some optimization problem. As it is the case for most heuristic methods, classical constructive heuristics do not provide knowledge of how far we are from the optimal solution. Many hard problems have special type of instances for which the constructed solution is optimal. Our new general constructive heuristic tries to provide the solution with guaranteed bounds. For that purposes, we need to have (i) constructive heuristic and (ii) special type of instances for which this heuristic provides optimal solution. Then, in each constructive step, if the best move is not possible, we change the original problem, tending to the one for which we know that our heuristic gives the optimal solution. The error is accumulated, giving the guaranteed bounds of heuristic solution. We also prove that such a solution is feasible for the original problem. The quality of bounds obtained by our heuristic is tested on TSP and MCP.

Approximate Minimal Curvature Surfaces in the Multiple Springback Algorithm for Construction of Prismatic Mesh Layers

Vladimir Garanzha[1], **Liudmila Kudryavtseva**[2]

[1] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* garan@ccas.ru
[2] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* liukudr@yandex.ru

Keywords: variational method, hyperelasticity, springback, prismatic mesh layer, minimal curvature surfaces

In order to construct prismatic mesh layers with precise control over mesh orthogonality, smoothness, layer thickness and outer shape of layer we suggest multiple springback algorithm. For each successive layer thin highly compressed layer of hyperelastic material is attached to the current outer surface. This material is expanded to prescribed thickness using minimization of special hyperelastic deformation energy. After expansion outer surface of new layer is constructed as an approximate minimal curvature surface. One can prescribe excessive thickness of each sublayer and the properties of the discrete curvature measure functionals. As a result one can construct prismatic layers for very complex geometries with undercuts and complex-shaped cavities. We demonstrate ability of multiple springback technique for construction of prismatic mesh layers for very complex geometries and present comparison with previous version of algorithm based on single springback algorithm.

Near-Boundary Layered Voronoi Meshing Algorithm for Planar Domains

Vladimir Garanzha[1], **Liudmila Kudryavtseva**[2], **Valeria Tsvetkova**[3]

[1] *Dorodnicyn Computing Center, FRC CSC RAS, Russia;* garan@ccas.ru
[2] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* liukudr@yandex.ru
[3] *Moscow Institute of Physics and Technology, Russia;*

Keywords: Voronoi mesh, variational method, Delaunay mesh, boundary mesh layer

We consider problem of constructing true Voronoi mesh where the union of true uncut Voronoi cells approximates the planar computational domain with piecewise-smooth boundary. Smooth boundary fragments are approximated by the Voronoi edges and Voronoi vertices are placed at the sharp boundary corners. We suggest special self-organization algorithm which covers the boundary of domain by a almost-structured band of non-simplicial Delaunay cells. This band consists of quadrangles on the smooth boundary segment and convex polygons around sharp corners.

Dual Voronoi mesh is double layered orthogonal structure where central line of the layer approximates the boundary. Overall Voronoi mesh has a hybrid structure and consists of high quality convex polygons in the core of domain and orthogonal layered structure near boundaries.

Stabilization of Moving Adaptive Meshes via Interpolation of Control Metrics for Equidistribution Principle

Vladimir Garanzha[1], **Liudmila Kudryavtseva**[2]

[1] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* garan@ccas.ru
[2] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* liukudr@yandex.ru

Keywords: mesh adaptation, mesh movement, equidistribution principle, variational method, quasi-isometric mappings

We suggest variational mesh deformation solver for the problem of constructing moving adaptive meshes using the concept of quasi-isometric mappings. The main problem related to quasi-isometric mesh solver is that the nonlinear variational problem is never solved exactly. As a result, for small changes of metric per time step one still can get large deformations due to gradual minimization. We abstain from the use of artificial time derivative in the mesh deformation solver since no mesh quality guarantees are available in this case, and one generally have to use adaptive filters to suppress moving mesh instabilities which were described in the seminal paper by Coyle, Flaherty, Ludwig, 1986. As an alternative we suggest special interpolation formulae for factorized metric tensors and show that now the deformation from one time level to another tends to isometric one when time-step is diminished resulting in the stable and continuous mesh deformation solver.

An Approximation Algorithm for the Network Capacitated Facility Location Problem

Edward Kh. Gimadi[1]

[1] *Sobolev Institute of Mathematics, SB RAS, Russia;* gimadi@math.nsc.ru

Keywords: capacitated facility location problem, approximation algorithm, network flow problem

We study the network Capacitated Facility Location Problem (CFLP). Given a graph $G(V, E)$ an a subset F of V. The vertices of G represent the customers and for each v in V the demand $d(v)$ is given. The subset F of V is a set of possible facility locations, and for each v in F there are given the cost $f(v)$ for opening a facility in v, and the restriction $a(v)$ on the capacity of facility opened in v. The edges of G represent the transportation network. For each edge e there cost $c(e)$ of transportation of a product unit is given. The goal is to open a subset of facilities that satisfies all the demands and minimizes the sum of opening costs of facilities and the delivering costs.

We present an approximation algorithm for the problem. The key idea of the algorithm is to reduce a specially relaxed CFLP to the network flow problem, and obtain a feasible solution of the CFLP by the greedy rounding off procedure.

An Improved Polynomial Algorithm for the Path Uniform Capacitated Facility Location Problem

Edward Kh. Gimadi[1], **Anna Kurochkina**[2]

[1] *Sobolev Institute of Mathematics, SB RAS, Russia;* gimadi@math.nsc.ru
[2] *SibGUTI, Novosibirsk, Russia;* a.potapova@ngs.ru

Keywords: uniform capacitated facility location problem, exact algorithm, polynomial time algorithm

The Capacitated Facility Location Problem (CFLP) states as follows. Given an n-element set of customers J and an m-element set of potential facility locations I. Each customer j has demand $b(j)$. For each i in I there are given the cost $f(i)$ of opening a facility at site i and the capacity $d(i)$. The cost of transportation of a product unit from i to j is equal to $c(i, j)$. It is required to open a subset of facilities such that all the demand is satisfied, and the total transportation and opening costs are minimized.

The problem is NP-hard, and it remains NP-hard in the case when the facility capacities are identical (Uniform CFLP). We consider the variant of the UCFLP, where sets I and J are the vertices of a weighted path-graph G. In 2009 Ageev, Kurochkin, and Gimady constructed an $O(m^4n^2)$ algorithm for the problem. In this report we present an algorithm with improved running-time $O(m^3n^2)$ for the UCFLP-path.

Comparison of Two Heuristic Algorithms for Competitive p-Median Facility Location Problem

Alexander Gnusarev[1], **Tatyana Levanova**[2]

[1] *Sobolev Institute of Mathematics SB RAS, Omsk Branch, Pevtsova str. 13, 644043 Omsk, Russia, Russia;* alexander.gnussarev@gmail.com

[2] *Sobolev Institute of Mathematics SB RAS, Omsk Branch, Russia;* levanova@ofim.oscsbras.ru

Keywords: discrete optimization, integer programming, location problems, p-median, elastic demand, variable neighborhood search, threshold algorithms, simulated annealing

The article is devoted to the development of the approximate methods for solving of competitive p-median facility location and design problem (CPFLDP) with flexible demand in the following formulation: the company plans to open its facility and make profit taking considering the fact that the Competitor's facilities are already located; there are several opening designs for each facility; the serviced demand share varies flexibly depending on where and what facility to locate. The Company's goal is to identify the locations and options for opening its new facility in order to attract the largest share of the entire customer demand. The specific demand nature leads to the objective function nonlinearity of the corresponding mathematical model and additional difficulties in finding the optimal solution. Variable neighborhood search and threshold algorithms are constructed, their experimental and comparative analysis is carried out, the obtained results are discussed.

Approximate Coalitional Equilibria in the Bipolar World

Andrei Golman[1], **Daniil Musatov**[2]

[1] *MIPT, Russia;* andrewsgolman@gmail.com
[2] *MIPT, Russia;* musatych@gmail.com

Keywords: coalitional stability, jurisdiction partition, approximate equilibrium

We study a discrete model of jurisdiction formation in the spirit of Alesina and Spolaore. A finite number of agents live along a line. They can be divided into several groups. If a group is formed, then some facility is located at its median and every member x of a group S with a median m pays $1/|S| + |x - m|$.

We consider the notion of coalitional stability: a partition is stable if no coalition wishes to form a new group decreasing the cost of all members. It was shown by Savvateev et al that no stable partition may exist even for 5 agents living at 2 points. We now study approximately stable partitions: no coalition wishes to form a new group decreasing all costs by at least ε.

In this work we define a relative measure of partition instability and consider bipolar worlds where all agents live in just 2 points. We prove the upper bound 7.1% on instability and construct an example where it is at least 5.3%.

Approximation of the Improper Linear Programming Problem with Restriction on the Norm of the Correction Matrix of the Left-Hand Side of the Constraints

Victor Gorelik[1], **Tatiana Zolotova**[2]

[1] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* vgor16@mail.ru
[2] *Financial University under the Government of the Russian Federation, Russia;* tgold11@mail.ru

Keywords: approximation of an improper problem, correction matrix, linear-quadratic programming

At present, methods of correction (approximation) of inconsistent systems of linear algebraic equations and inequalities and improper linear programming problems have become widespread. In this paper we consider an improper linear programming problem with an empty admissible set. It is formalized in the form of the problem of maximizing the initial criterion with the upper bound on the Frobenius norm of the correction matrix of the parameters of the left-hand side of the constraints. A range of threshold values is found for which the problem has a solution. In its original form, it is not a convex programming problem (it contains bilinear constraints). Therefore, a direct solution by optimization methods can lead, as shown by computational experiments, to local extrema. A method for its reduction to the problem of linear-quadratic programming was developed and its solution was found in an analytical form, which enabled the use of standard matrix calculations.

Optimization Technology for Approximation of System of a Partial Differential Equations System of the Second Order

Aleksander Gornov[1], **Timur Shamirzayev**[2]

[1] *Matrosov Institute for System Dynamics and Control Theory of SB RAS, Russia;* gornov.a.yu@gmail.com

[2] *Rzhanov Institute of Semiconductor Physics of SB RAS, Russia;* sha_tim@mail.ru

Keywords: Optimal control, Diffusion type system, Numerical algorithms

The problem of modeling the dynamics of distribution of diffusing material is considered. In the general case, it is necessary to solve a system of partial differential equations of the second order of the diffusion type with special boundary and intermediate conditions. For the solution it is proposed to use the method of semidiscretization (the "direct" method) and the reduction of the original problem to the problem of optimal control in a system of ordinary differential equations. As control actions boundary conditions are considered for both equations of the system, as the target functional – fines for violation of boundary and intermediate conditions. The results of computational experiments are presented.

Branch and Bound Algorithm for the Single Machine Scheduling Problem with Release and Delivery Times

Natalia Grigoreva[1]

[1] *State Petersburg University, Russia;* n.s.grig@gmail.com

Keywords: single processor, branch and bound algorithm, release and delivery time, inserted idle time, optimal schedule

The single machine scheduling problem is one of the classic NP-hard optimization problems, and it is useful in solving flowshop and jobshop scheduling problems.

The goal of this paper is to prepare algorithms for scheduling problem, where set of tasks is performed on a single processor. Each task has a release time, a processing time and a delivery time. At most one job can be processed at a time, but all jobs may be simultaneously delivered. Preemption is not allowed.

The objective is to minimize the time, by which all tasks are delivered. In this paper, we propose an approximate IIT algorithm named IJR. Then by combining the IJR algorithm and branch and bound method, we develop BB/ILR algorithm, which can find optimal solutions. We use a binary branching rule, where at each branch node, a complete schedule is generated.

To illustrate the effectiveness of our algorithms we tested them on randomly generated set of tasks.

Maximum Flow in Graphs with Limited Arc and Node Capacities

Iakov Grinberg[1]

[1] *Institute for Information Transmission Problems RAS (IITP RAS), Russia;*
greenjak@yandex.ru

Keywords: Flow maximization, Node capacity, Flows in networks

An algorithm for determining the maximum flow in a mixed graph whose chain decomposition contains only simple chains is described. The algorithm consists of sequential steps, with each subsequent step is an algorithm to increase the flow already existing in the graph. At each step, the original graph is transformed into another, in which the flow - saturated nodes are split into two - one of these nodes is incident to the incoming flow arcs, the other – to the outgoing flow arcs. The nodes are connected by a directed arc with a capacity equal to the node's capacity. For such a graph, an additional graph is constructed, including arcs over which an additional flow can be transmitted. The algorithm provides the increasing of the flow by a chain being a simple chain in the original graph. The algorithm splits into a series of independent computational subtasks of the reachability problem of one node from another in a graph and admits parallel and distributed realizations.

Scheduling of Locomotives' Maintenance TS-2 in a Depot

Egor Grishin[1], **Semen Galakhov**[2], **Alexander Lazarev**[3]

[1] *Moscow State University, Russia;* egor19990209@ya.ru

[2] *Moscow State University, Russia;* galakhov.sa@physics.msu.ru

[3] *Institute of Control Sciences of the Russian Academy of Sciences, Russia;* jobmath@mail.ru

Keywords: Railway scheduling, Linear programming, Heuristic algorithms

We consider several heuristic algorithms for scheduling maintenance of locomotives in the depot consisting of three observation ditches. Here six algorithms for scheduling maintenance of locomotives in the depot for some cases are presented. These algorithms give opportunity to set priority of service requirements by various permutations. We carried out computer experiments to calculate the absolute error in comparison with the method of iteration giving the absolute minimum of the objective function. As a result the proposed algorithms provide scheduling for less computer time with small errors compared to standard optimizers as IBM IlogCplex.

Synthesis of Conical Phased Antenna Arrays Optimization of Amplitude Distribution Parameters

Mikhail Indenbom[1], **Viktor Izhutkin**[2], **Anton Sharapov**[3], **Alexander Zonov**[4]

[1] *All-Russian Scientific Research Institute of Radio Engineering, Russia;*
IndenbomMV@mpei.ru

[2] *National Research University Moscow Power Engineering Institute, Russia;*
izhutkin@yandex.ru

[3] *National Research University Moscow Power Engineering Institute, Russia;*
deadkingser@gmail.com

[4] *National Research University Moscow Power Engineering Institute, Russia;*
zonoffalexander@gmail.com

Keywords: synthesis of cpaa, amplitude distributional, particle swarm optimization, gradient method

In the synthesis of conical phased antenna arrays (CPAA), special attention is paid to its characteristics – a high intensification coefficient (IC) and a low level of side lobes (LSL).

There is no single effective approach to the solution of the problem, in view of the variety of ways of setting and optimization methods.

In this paper, we consider the solution of the problem of synthesis of conical PAA by optimizing the parameters of the amplitude distribution – with the limitation of the largest LSL it will be necessary to maximize the IC. The solution of the problem is proposed by the methods of random search (based on the Particle Swarm Optimization) and classical gradient methods, as well as subsequent comparison and evaluation of the results obtained.

The speed is provided by using a fast Fourier transform to calculate the target function.

One-Level Menu Optimization: How to Make Conventional Things Better

Evgeny Ivanko[1]

[1] *IMM UBr RAS, Russia;* evgeny.ivanko@gmail.com

Keywords: Menu optimization, HCI, access time, convenience, balance, UPGMA, Fitt's law

In this article I address the problem of minimizing 1-level horizontal menu's access time while preserving the menu's appearance the user is accustomed to. The proposed mathematical formalization shows high computational complexity even for the considered simplified case. As an alternative, a heuristic is proposed to produce feasible solutions of the initial non-simplified version of the problem in polynomial time; 2 results of application of the heuristic are presented.

Influence of Altruists on Connectivity of Dynamic Wireless Mesh Network

Evgeny Ivanko[1], **Pavel Chentsov**[2], **Yaroslav Salii**[3]

[1] *IMM UBr RAS, Russia;* evgeny.ivanko@gmail.com
[2] *IMM UBr RAS, Russia;* chentsov.p@mail.ru
[3] *IMM UBr RAS, Russia;* watsuteru@gmail.com

Keywords: k-connectivity, mesh network, wireless network, unit disk graph, altruism

A model of decentralized mesh network consisting of moving agents with a limited connection radius is considered. The agents in the model can play two roles: neutral (moving in accordance with the Correlated Random Walk law) and altruists (moving with the purpose to maximize the 2-connectivity of the Euclidean graph corresponding to the network at each particular time). We study the dependence between a measure of the network connectivity and the share of altruists in the model. In addition to offering purely theoretical insights into the behavior of complex systems, the considered model can help to plan p2p Wi-Fi networks in big cities or coordinate emergency response groups.

Optimization in Post-Processing of Molecular Docking Results

Alexey Ivanov[1], **Victor Emelianov**[2]

[1] *Ural Federal University, Russia;* av.ivanov.2014@yandex.ru
[2] *Ural Federal University, Russia;* v.v.emelianov@urfu.ru

Keywords: molecular docking, post-processing, binding site, clustering, maximum weight clique

The work is devoted to the construction and investigation of the post-processing algorithm of the results of molecular docking, which consists in finding the most reliable conformation of the ligand molecule in the ligand-protein binding site. Based on the results of docking programs, a weighted conformational graph is constructed and for this graph the maximum weight clique problem is solved. The result of the algorithm is ranked conformational clusters with box-estimates of the active binding site. The efficiency of the algorithm is demonstrated on a number of ligand-protein complexes from the PDBbind database.

Alternative Theorem for Differential Games with Strongly Convex Admissible Control Sets

Grigorii Ivanov[1], **Maxim Golubev**[2]

[1] *Moscow Institute of Physics and Technology, Russia;* g.e.ivanov@mail.ru
[2] *Moscow Institute of Physics and Technology, Russia;* maksimkane@mail.ru

Keywords: Differential game, Strongly convex set, Minkowski sum and difference

A linear differential game with strongly convex admissible control sets and a smooth target set is considered. For such a differential game we obtain the alternative theorem. This theorem states that for any initial position either there is a program strategy of pursuer that guarantees the capture or there is a program strategy of evader that guarantees the evasion. This result is based on the commutativity of Minkowski sum and difference for sets with special properties of strong and weak convexity in Banach space.

The Nearest Point Theorem for Weakly Convex Sets in Asymmetric Seminormed Spaces

Grigorii Ivanov[1], **Mariana Lopushanski**[2], **Maxim Golubev**[3]

[1] *Moscow Institute of Physics and Technology, Russia;* ivanov.ge@mipt.ru
[2] *Moscow Institute of Physics and Technology, Russia;*
masha.alexandra@gmail.com
[3] *Moscow Institute of Physics and Technology, Russia;* maksimkane@mail.ru

Keywords: Weakly convex sets, Asymmetric seminorm, Metric projection

Weakly convex sets in asymmetric seminormed spaces are considered. We prove that any point from some neighborhood of such a set has the unique nearest point in the set. The proof of the nearest point theorem is based on the theorem about the diameter of ε-projection which is also important in approximation theory. The notion of weakly convex sets in asymmetric seminormed spaces generalizes known notions of sets with positive reach, proximal smooth sets and prox-regular sets. By taking the Minkowski functional of the epigraph of some convex function as a seminorm, the results obtained for weakly convex sets can be applied to weakly convex functions whose graphs are weakly convex sets with respect to this seminorm.

Composite Optimization for the Resource Allocation Problem

Anastasia Ivanova[1], **Alexander Gasnikov**[2], **Pavel Dvurechensky**[3]

[1] *MIPT, Russia;* anastasiya.s.ivanova@phystech.edu
[2] *MIPT, Russia;* gasnikov@yandex.ru
[3] *WIAS, Germany;* pavel.dvurechensky@gmail.com

Keywords: decentralized pricing, primal-dual method, composite method

We consider the resource allocation problem and it's numerical solution. In the case when the number of the resource constraints is large we developed a composite primal-dual technique to solve the problem. We also propose a new conception of master-slave communication based on the notion of controller for each of the resource constraints. The most important what we suggest economically interpretive composite distributed algorithm for the resource allocation problem. Solving this problem we have some additional difficulties (we have to bound dual multiplyers we have to obtain the solution of the primal problem from the dual one with the desired precision e.t.c.). We concentrate on this difficulties.

The Combined Computer Model of the Solution of Conflict Situations

Viktor Izhutkin[1]

[1] *National Research University MPEI, Russia;* izhutkin@yandex.ru

Keywords: Lanchester's model, bimatrics game, the combined program realization

Modifications of model of war of Lanchester are developed. The bimatrix games describing economic aspect of various conflicts are considered. The combined program realization of models is enabled. Changing parameters of the visualized Lanchester's model, we can define influence of values of these parameters on model and establish interrelation with characteristics of the real situation, and also carry out forecasting of a situation. At the same time matrixes of the visualized bimatrix game change that allows to define influence of values of parameters of the combined model and on the decision of a game and also to carry out game forecasting of a financial situation for the considered problem. Results of use of model for the known problems (Iraq, Afganistan, Syria) in military sphere are given.

Computer Model of Colony of Microorganisms Acquired Pneumonia for Optimization of the Concentration of Antibiotic

Viktor Izhutkin[1], **Ilya Kocheshkov**[2]

[1] *NRU MPEI, Russia;* izhutkin@yandex.ru
[2] *NRU MPEI, Russia;* ilya.kochesh@yandex.ru

Keywords: computer model, pneumonia, optimization of antibiotic

Visualized computer realization of mathematical model of sensitivity decrease of microorganisms causing community acquired pneumonia to the action of antibiotics is presented. The sensitivity decrease to the action of antibiotics becomes more important as result of uncontrolled use of antibiotics. In the process of adaptation, bacteria acquire a resistance to action of antibiotic. Therefore, further use of the antibiotic is ineffective, because the bacteria continue to multiply and the population increases. It is necessary correctly to calculate concentration of antibiotic for the treatment to avoid disease progression. Visualization of mathematical model of sensitivity decrease of microorganisms allows investigate the influence of parameters of bacteria and antibiotic on the bacteria's population size, which allows solving the problem of optimization of the concentration of antibiotic for bacteria with different parameters.

On a Linear Control Problem under Interference with a Payoff Depending on the Modulus of a Linear Function and an Integral

Igor' Izmest'ev[1], **Viktor Ukhobotov**[2]

[1] *Chelyabinsk State University, Russia;* j748e8@gmail.com
[2] *Chelyabinsk State University, Russia;* ukh@csu.ru

Keywords: control, interference, differential game

We consider the problem of controlling the rod, which is attached to the rotor of the electric motor. The control is the amount of voltage applied to the electric motor. The quality criterion is the sum of the angle deviation module that forms the rod with the vertical axis, at a given time, and the integral of the square of the voltage value. This problem is an example of a more general linear control problem under the action of an uncontrolled interference. The possible values of the interference belong to a compact set. The control is sought as the product of a scalar function and a vector function, values of which belong to a connected symmetric compact. The terminal part of the payoff depends on the modulus of a linear function of the phase vector. The integral part of the payoff is the integral on the segment of a degree of scalar function.

Distributed Consensus on Homogeneous Spaces

Vladimir Jaćimović[1], **Milojica Jaćimović**[2], **Nevena Mijajlovic**[3]

[1] *University of Montenegro, Montenegro;* vladimir@jacimovic.me
[2] *University of Montenegro, Montenegro;* milojica@jacimovic.me
[3] *University of Montenegro, Montenegro;* nevenamijajlovic@hotmail.com

Keywords: Distributed consensus, Optimization problem, cooperative control, multi-agent system

The broad field of distributed and cooperative control comprises various problems of consensus, coordination and formation keeping in multi-agent systems. These problems are usually stated on some special non-Euclidean manifolds, such as homogeneous spaces or compact Lie groups... Consensus can be viewed as a solution of certain optimization problem. One paradigmatic and highly nontrivial example is consensus problem on the unit circle.

We will consider the system of N agents that communicate to each other through the connected graph. Introducing disagreement cost function, the gradient system for this function yields a famous Kuramoto model of coupled oscillators. This system provides a distributed protocol for achieving consensus on the unit circle. In an analogous way we will study consensus on some higher-dimensional manifolds, such as spheres or matrix Lie groups. These examples are of special interest due to numerous applications.

On the Coefficient Inverse Problem of Heat Conduction in a Degenerating Domain

Muvasharkhan Jenaliyev[1], **Murat Ramazanov**[2], **Madi Yergaliyev**[3]

[1] *Institute of Mathematics and Mathematical Modeling, Kazakhstan;* muvasharkhan@gmail.com

[2] *Buketov Karagandy State University, Kazakhstan;* ramamur@mail.ru

[3] *Institute of Mathematics and Mathematical Modeling, Kazakhstan;* Ergaliev.madi.g@gmail.com

Keywords: coefficient inverse problem, heat equation, degenerating domain

In the bounded domain that degenerates at the initial moment of time, we consider the coefficient inverse problem for the heat equation with inhomogeneous boundary conditions. To this problem we associate an inverse problem in an unbounded domain which also degenerate at the initial instant of time. On the basis of our previously established results we find a solution to the auxiliary inverse problem. Further, by narrowing the solution of the auxiliary problem to a bounded domain we obtain the solution of the original inverse problem.

Pattern Recognition with the Aid of Derivative Disproportion Functions

Viacheslav Kalashnikov[1], **Viktor V. Avramenko**[2], **Nataliya Kalashnykova**[3]

[1] *ITESM, Campus Monterrey, Mexico;* kalash@itesm.mx
[2] *Sumy State University (SumDU), Sumy, Ukraine;* avr@sumdu.edu.ua
[3] *Dept. Physics & Maths (FCFM), University Autonomous Nuevo Leon (UANL), Mexico;* mxkalash@yahoo.de

Keywords: Pattern recognition, cryptographic systems, derivative disproportion functions, decoding algorithms

The aim of this paper is twofold: (i) to develop a cryptographic system, and (ii) to provide a pattern recognition technique to discern the form of a process governing function. Both problems are solved with the aid of derivative disproportion functions.

We present an algorithm for designing a cryptographic system, in which the derivative disproportion functions are used. The symbols to be transmitted are encrypted by the sum of these functions multiplied by randomly generated coefficients. A new algorithm is proposed for decoding the received messages by using some important properties of the derivative disproportion functions.

Also, the same derivative disproportion functions serve to recognize the form of a real-valued function governing a dynamic process. This technique helps to decide to which class of functions the mapping in question belongs, independently of its parameter values.

Numerical experiments confirm the algorithms to be highly competitive, robust and reliable.

Digital Hyperspectral Holography in White Light: Principles and Algorithms

Sergey Kalenkov[1], **Georgy Kalenkov**[2], **Alexander Shtanko**[3]

[1] *Moscow Polytech, Russia;* kaser45@gmail.com
[2] *Microholo Ltd, Russia;* kalenkov@mail.ru
[3] *MGTU "Stankin", Russia;* valdaisky@gmail.com

Keywords: holography, Fast Fourier Transform (FFT), coherence, correlation, optical information processing

Incoherent digital holography is a new and rapidly developing field of modern optics. In addition to the purely theoretical interest associated with the use of modern methods of digital optical processing of random signals, incoherent hyperspectral holography has a number of important applications in holographic reconstruction of biomedical objects and a number of other areas of optical information processing. In a series of our works we first proposed a theoretical model and an appropriate algorithm for recording and reconstructing digital hyperspectral holograms in white light which later we experimentally verified. This report is devoted to the discussion and further development of the methods we have proposed earlier. A number of new experimental results on registration and reconstruction of digital hyperspectral holograms of some micro-objects are also presented.

Distressed Assets in a Normative Dynamic Model of Kazakh Economy

Almas Kalimoldaev[1], **Bulat Mukhamediev**[2], **Nicholas Olenev**[3]

[1] *Al-Farabi Kazakh National University, Almaty, Kazakhstan;* kalimoldaev85@gmail.com

[2] *Al-Farabi Kazakh National University, Kazakhstan;* Bulat.Mukhamediev@kaznu.kz

[3] *Doronicyn Computing Centre, FRC CSC RAS, Russia;* nolenev@mail.ru

Keywords: distressed assets, Kazakh economy, normative dynamic model, numerical solution, parallel calculations

The paper presents a normative mathematical model of Kazakh economy with distressed assets in banking sector. The model contains a lot of unspecified parameters which are not defined directly by the data of economic statistics. A method of identification of the model parameters is a type of global optimization problem. Parallel calculations are used for estimation of model parameters by statistical data of the Kazakh economy 2000-2016.

About the Numerical Solution of Optimal Control Problems for Complex Electric Power Systems

Maksat Kalimoldayev[1], Assel Abdildayeva[2], Maksat Akhmetzhanov[3], Beglan Namazbayev[4]

[1] *Institute of Information and Computational Technologies, Kazakhstan;*
mnk@ipic.kz

[2] *Institute of Information and Computational Technologies, Kazakhstan;*
abass_81@mail.ru

[3] *Institute of Information and Computational Technologies, Kazakhstan;*
maks714@mail.ru

[4] *Institute Information and Computational Technologies, Kazakhstan;*
nbd-81@mail.ru

Keywords: sufficient optimality conditions, power system, optimality, control, iterative algorithm

This article discusses the numerical solution of optimal control problems for complex electric power systems using iterative algorithm. Also, the issues of solving optimal control of nonlinear system of ordinary differential equations in two different cases have been considered. The studied model, in particular, describes the control processes in electric power systems. The proposed solution methods follow the principle of the extension of extreme problems, based on sufficient optimality conditions of V. F. Krotov. We considered the special case of optimal control problems. Numerical experiments showed sufficient efficiency of the implemented algorithms. The problem of optimal motion control of electric power system is graphically illustrated in proposed numerical example.

The Population Groups Human Capital Dynamics Model Research

Ivan Kamenev[1]

[1] *Government budget institution Federal research center of Informatics and Management of the Russian science academy, Russia;* igekam@gmail.com

Keywords: human capital, dynamic modeling, optimization, internal correlation

The study describes human capital modeling as economy production factor. The modeled object includes population groups of people with common qualifications characteristics. Each group is considered as independent economic agent. For this object was constructed a dynamic two-factor optimization model that relates the group survival to its quantity and qualification. The model's main feature is the culture general level (medium qualification) influence on the investments in qualifications effectiveness consideration. The model research aims to determine the possible and optimal group strategies. The most important model dynamics manifestation is its so-called "race for the average", i.e. groups' mutual influence on each other qualifications.

Universal Intermediate Gradient Method for Convex Problems with Inexact Oracle

Dmitry Kamzolov[1], **Pavel Dvurechensky**[2], **Alexander Gasnikov**[3]

[1] *Moscow Institute of Physics and Technology, Russia;* dkamzolov@yandex.ru
[2] *Weierstrass Institute for Applied Analysis and Stochastics, Russia;* pavel.dvurechensky@wias-berlin.de
[3] *Moscow Institute of Physics and Technology, Russia;* gasnikov@yandex.ru

Keywords: Convex optimization, First-order methods, Inexact oracle, Intermediate gradient methods, Complexity bounds

We propose new first-order methods for minimization of a sum of a simple convex function and a convex function with inexact Holder-continuous subgradient on a simple convex set. We propose Universal Intermediate Gradient Method. Our method enjoys both the universality and intermediateness properties. Following the ideas of Y. Nesterov on Universal Gradient Methods, our method does not require any information about the Holder parameter and constant and adjusts itself automatically to the local level of smoothness. On the other hand, in the spirit of Intermediate Gradient Method, our method is intermediate in the sense that it interpolates between Universal Gradient Method and Universal Fast Gradient Method. This allows to balance the rate of convergence of the method and rate of the oracle error accumulation. Under additional assumption of strong convexity of the objective, we show how the restart technique can be used to obtain an algorithm with faster rate of convergence.

Using Sparse Principal Component Methods for Approximating the Restricted Isometry Constants of Complex-Valued Tight Frames

Igor Kaporin[1]

[1] *Dorodnicyn Computing Centre, Federal Research Center "Computer Science and Control" of Russian Academy of Sciences, Russia;* igorkaporin@mail.ru

Keywords: restricted isometry property, sparse principal component analysis, complex-valued tight frames, iterative numerical methods

For the estimation of constants in the standard restricted isometry condition for a complex-valued tight frame, various generalizations of techniques related to Sparse Principal Component Analysis are applied. We consider certain optimization reformulations of the problem and iterative algorithms for approximating sparse solutions, such as recently proposed Truncated Power method of Yuan and Zhang (2013). For the best methods, massively-parallel implementations are developed and tested on the MVS-10P supercomputer of JSCC RAS. The efficiency of methods is verified by numerical results obtained for several important test examples of tight frames. The computed approximations of restricted isometry constants are compared with the exact values obtained by direct search (if available).

An Exact Algorithm of Searching for the Largest Size Cluster in an Integer Sequence 2-Clustering Problem

Alexander Kelmanov[1], Sergey Khamidullin[2], Vladimir Khandeev[3], Artem Pyatkin[4]

[1] *Sobolev Institute of Mathematics, Siberian Branch of the Russian Academy of Sciences, Russia;* kelm@math.nsc.ru

[2] *Sobolev Institute of Mathematics, Siberian Branch of the Russian Academy of Sciences, Russia;* kham@math.nsc.ru

[3] *Sobolev Institute of Mathematics, Siberian Branch of the Russian Academy of Sciences, Russia;* khandeev@math.nsc.ru

[4] *Novosibirsk State University; Sobolev Institute of Mathematics, Russia;* artempyatkin@gmail.com

Keywords: Euclidean space, sequence, 2-partition, longest subsequence, quadratic variation, NP-hard problem, integer coordinates, exact algorithm, fixed space dimension, pseudopolynomial running time

We consider a problem of 2-partitioning a finite sequence of points in Euclidean space into clusters so as to maximize the size of one cluster under two constraints. The first constraint is on the indices of clusters elements. The second one is on the value of a clusterization function. The function is the sum over both clusters of the intracluster sums. Each of these sums is the sum of squared distances between cluster elements and the cluster center. The center of one cluster is unknown and determined as the centroid, while the center of the other one is the origin. In the first constraint, the difference between every two consecutive indices of the elements included in the cluster with unknown centroid is bounded from above and below by some constants. We have shown the strong NP-hardness of the problem. In addition, we have proved an exact algorithm for the integer case of the problem. If the space dimension is fixed, our algorithm runs in a pseudopolynomial time.

NP-Hardness of Some Max-Min Clusterization Problems

Alexander Kelmanov[1], **Vladimir Khandeev**[2], **Artem Pyatkin**[3]

[1] *Sobolev Institute of Mathematics, Siberian Branch of the Russian Academy of Sciences, Russia;* kelm@math.nsc.ru

[2] *Sobolev Institute of Mathematics, Siberian Branch of the Russian Academy of Sciences, Russia;* khandeev@math.nsc.ru

[3] *Novosibirsk State University; Sobolev Institute of Mathematics, Russia;* artempyatkin@gmail.com

Keywords: Euclidean space, clustering, max-min problem, NP-hardness, quadratic variation

We consider some consimilar problems of searching for disjoint subsets in the finite set of points in Euclidean space. In these problems, it is required to maximize the minimum subset size so that the value of each intracluster quadratic variation would not exceed a given constant. In the paper, we have proved that all the problems are NP-hard even on a line.

Combinatorial Optimization on the Lattice of Cubes

Ruben V. Khachaturov[1]

[1] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;* rv_khach@yahoo.ie

Keywords: Lattice Theory, Lattice of Cubes, hypercubes, combinatorial optimization, supermodular functions, supermodular programming, multicriteria optimization, equivalence set, pseudometric space, inverse problems

It is shown that the new mathematical object in the Lattice Theory the Lattice of Cubes can be used for setting and solving of the different types of optimization problems on it. These can be both single criterion problems and multicriteria problems. Examples of such problems are given. The possibility of applying previously developed efficient optimization algorithms to the formulation and solution of new classes of problems on lattices of cubes is described. A method for solving inverse multicriteria problems in a multidimensional pseudometric space is proposed for solving the multicriteria problems on the Lattice of Cubes. It is shown that the proposed method of finding the equivalence set for solving multiobjective (multicriteria) discrete optimization problems is advantageous over finding the set of Pareto optimal decisions. The solution of a particular problem of this type is presented.

Polynomial Time Approximation Schemes for the Euclidean Capacitated Vehicle Routing Problem with Time Windows

Michael Khachay[1], **Yuri Ogorodnikov**[2]

[1] *Krasovsky Institute of Mathematics and Mechanics, Russia;*
mkhachay@imm.uran.ru

[2] *Krasovsky Institute of Mathematics and Mechanics, Russia;*
yogorodnikov@gmail.com

Keywords: Capacitated Vehicle Routing Problem, Time window, EPTAS

Capacitated Vehicle Routing Problem (CVRP) is the well known combinatorial optimization problem stemming from highly popular models of operations research. It is known that CVRP is strongly NP-hard even in the Euclidean plane and can be approximated well in finite-dimensional Euclidean spaces. Nevertheless, approximability of the modification of CVRP, where feasible routes are constrained by time-delivery (also known as "time-windows") constraints. To the best of our knowledge, quasi-polynomial approximation scheme proposed recently by Song et al. for the Euclidean CVRP with fixed number of consecutive time-delivery intervals is the unique known result in this field. In this paper, we propose an improved approximation scheme for this problem. For any fixed capacity q and number of time windows p, the scheme proposed is an Efficient PTAS with time complexity $O(n^3 + \exp((1/\varepsilon)^3))$. Moreover, it remains PTAS for $p^4q^3 = O(\log n)$.

The Justification for the Use of the Theory Intelligence Methods as a Basic Tool for Modeling Semantic Relations of a Language System

Nina Khairova[1], **Orken Mamyrbayev**[2], **Natalia Sharonova**[3], **Kuralai Mukhsina**[4]

[1] *National Technical University "Kharkiv Polytechnic Institute", Ukraine;* nina_khajrova@yahoo.com

[2] *Institute of Information and Computational Technologies, Kazakhstan;* morkenj@mail.ru

[3] *National Technical University "Kharkiv Polytechnic Institute", Ukraine;* nvsharonova@mail.ru

[4] *Al-Farabi Kazakh National University, Kazakhstan;* kuka_ai@mail.ru

Keywords: complex language system, semantic processing of texts, intelligence theory, finite predicates algebra, binary logical network

The number of proposed approaches to the semantic processing of texts is constantly growing. However, in most cases, they are based on a prior domain knowledge representation. While the growth in the volume of textual information leads to a constant dynamic expansion and change of subject areas. The problem of developing universal models of semantic processing of texts is related to the issues of knowledge extraction from natural language texts.

The study presents an argument for using models of the intelligence theory as basic means of modeling semantic relations of a complex language system. The application of the finite predicates algebra as an optimal tool for formalizing semantic relations of elements of different language levels is shown. A binary logical network, which is a graphical expression of a multiplace predicate decomposition, is constructed for a formal description of the relations between knowledge extracted from text documents and local semantic knowledge fields.

Piecewise Linear Bounding Functions in Univariate Global Optimization

Oleg Khamisov[1], **Mikhail Posypkin**[2], **Alexander Usov**[3]

[1] *Melentiev Energy Systems Institute of Siberian Branch of the Russian Academy of Sciences, Russia;* globopt@mail.ru

[2] *Federal Research Center Computer Science and Control of RAS, Russia;* mposypkin@gmail.com

[3] *Federal Research Center Computer Science and Control of RAS, Russia;* alusov@mail.ru

Keywords: univariate global optimization, piecewise linear functions, estimators, deterministic methods

The paper addresses the problem of constructing lower and upper bounding functions for univariate functions. This problem is of a crucial importance in global optimization where such bounds are used by deterministic methods to reduce the search area. It should be noted that bounding functions are expected to be relatively easy to construct and manipulate with. We propose to use piecewise linear estimators for bounding univariate functions. The rules proposed in the paper enable an automated synthesis of lower and upper bounds from the function's expression in an algebraic form. Numerical examples presented in the paper demonstrate the high accuracy of the proposed bounds.

Approximation Scheme for a Problem of Searching for the Largest Subset

Vladimir Khandeev[1]

[1] *Sobolev Institute of Mathematics, Siberian Branch of the Russian Academy of Sciences, Russia;* khandeev@math.nsc.ru

Keywords: Euclidean space, largest subset, quadratic variation, NP-hard problem, approximation scheme

The paper is addressed to one strongly NP-hard problem of searching for the largest subset in the finite set of points in Euclidean space. We present an approximation scheme for this problem.

Necessary Conditions of Overtaking Optimality and Convergence of Subdifferentials

Dmitry Khlopin[1]

[1] *Krasovskii Institute of Mathematics and Mechanics, Russia;*
khlopin@imm.uran.ru

Keywords: Infinite horizon control problem, overtaking optimal control, convergence of subdifferentials

In this paper we investigate necessary conditions of optimality for infinite-horizon optimal control problems with overtaking optimality as an optimality criterion. Applying the theorem on convergence of subdifferentials, for the case of lower semicontinuity of the payoff function in state variable, we research a boundary condition on the co-state arc that is necessary for the optimality. We also show that, under additional assumptions on the payoff function's asymptotic behavior, the Pontryagin Maximum Principle with this condition becomes a complete system of relations, and this boundary condition points out the unique co-state arc through a Cauchy-type formula. An examples are given to clarify the application of this formula as an explicit expression of the co-state arc.

On Strategies Guaranteeing Uniform Value

Dmitry Khlopin[1]

[1] *Krasovskii Institute of Mathematics and Mechanics, Russia;*
khlopin@imm.uran.ru

Keywords: Dynamic programming principle, dynamic games, uniform value, Abel mean, Cesàro mean

We consider dynamic games, its framework is not limited to e.g. differential games and could accommodate both discrete and continuous time. Assuming common dynamics, we study two game families with total payoffs that are defined Cesàro and Abel averages of the running costs. We study robust strategies that would provide a near-optimal total payoff for these families (either for all sufficiently large planning horizons, or all sufficiently small discounts). Under assumptions of Dynamic Programming Principle and the closedness with respect to concatenation, we announced the following result: if we know an uniformly optimal strategy for one of the families, and its value functions converge uniformly, then, an uniformly optimal strategy for the both families can be constructed.

Approximation Algorithms for Geometric Intersection Problems

Konstantin Kobylkin[1]

[1] *Krasovsky Institute of Mathematics and Mechanics, Russia;*
kobylkinks@gmail.com

Keywords: computational geometry, constant factor approximation algorithms, Hitting Set problem

Fast constant factor approximation algorithms are devised for an NP- and W[1]-hard problem of intersecting a set of straight line segments with the least cardinality set of disks of radii $r > 0$, where the set of segments forms a straight line drawing $G = (V, E)$ of a planar graph. Exploiting connection of the problem with the Hitting Set problem, an $\left(50 + 52\sqrt{\frac{12}{13}} + \varepsilon\right)$-approximate $O\left(\left(|E|^2 + \frac{|E|\log|E|}{\varepsilon^2} + \frac{\log|E|}{\varepsilon^3}\right)|E|^2 \log|E|\right)$-time algorithm is given. More accurate $(34 + 24\sqrt{2} + \varepsilon)$-, $\left(12 + 6\sqrt{3} + \varepsilon\right)$- and $\left(34 + 38\sqrt{\frac{15}{19}} + \varepsilon\right)$-approximations are also proposed for the case where G is any subgraph of either an outerplane or a Gabriel graph or a Delaunay triangulation, which work within the same complexity bounds, where $\varepsilon > 0$ is an arbitrary small constant.

Stochastic Tabu Search for the Single Machine Scheduling with Setups and Storage

Yury Kochetov[1], **Polina Kononova**[2]

[1] *Sobolev Institute of Mathematics, Russia;* jkochet@math.nsc.ru
[2] *Sobolev Institute of Mathematics, Russia;* polik83@ngs.ru

Keywords: scheduling, local search, sequence-dependent setup time

We consider the following single machine scheduling problem originated from the tile industry. The factory produces homogeneous products of several types. Products of the same type are produced in batches. Minimum batch size is known. The sequence-dependent batch setup time is given.

We know a set of jobs. Each job consists of a set of operations. Each operation corresponds to manufacturing of a product with a certain type and quantity. The factory has storage with unlimited capacity and some quantity of each product. We can use the product from the storage instead of producing it.

The tardiness of job is defined as the positive time difference between the due date of job and the completion time of the last operation of this job. We want to find a schedule which minimizes the total weighted tardiness.

We design a stochastic tabu search to tackle this NP-hard problem. Computational results for real-world instances from the tile industry are discussed.

Comparison of Two Matheuristics for the Strategic Planning Public-Private Partnership

Yury Kochetov[1], **Alexander Zyryanov**[2], **Sergey Lavlinskii**[3]

[1] *Novosibirsk State University, Russia;* jkochet@math.nsc.ru
[2] *Sobolev Institute of Mathematics, Russia;* alexander.zyryanov44@gmail.com
[3] *Sobolev Institute of Mathematics, Russia;* lavlin@math.nsc.ru

Keywords: tabu search, high point problem, bi-level integer linear programming

We study a new bi-level linear integer programming model for the strategic planning of the public-private partnership. This model is an extension of the previously studied models where the ecological, infrastructure, and production projects have known schedules into the planning horizon if they start. We compare two matheuristics for this bi-level problem: a stochastic tabu search and matheuristic based on the high point reformulation. The both methods use local search according to the upper level variables. The optimal solution for the lower level is obtained by CPLEX software. To reduce the running time of each local search iteration, we use randomized flip and swap neighborhoods. To evaluate the neighboring solutions we solve the lower level problem approximately with a small fixed deviation from the optimum. Computational results for real world instances for the Transbaikalian polymetal fields are discussed.

Multiobjective Optimization on Permutations with Applications

Liudmyla Koliechkina[1], **Oksana Pichugina**[2]

[1] *University of Lodz, Poland;* ludapl@ukr.net

[2] *National Aerospace University "Kharkv Aviation Institute", Ukraine;* oksanapichugina1@gmail.com

Keywords: multiobjective optimization, combinatorial optimization, permutations, graph, the Directed Structuring Method

A method of multiobjective optimization on permutations (MOP) is proposed based on the Directed Structuring Method and using Graph Theory. Prospects of applying graph techniques are caused by representability of the feasible domain by graph vertices. It yields advantages in using traditional methods, as well as in developing new ones. Our method is a generalization onto multiobjective problems of the Method for Sequential Analysis of Variants. Most problems on combinatorial configurations sets (CCS) are NP-hard and for exact solution require enumerating a factorial number of variants. To decrease it, the method includes: a choice of an unconstraint MOP method; a choice of a method for generating admissible solution sequence for constraint MOP adapted to target function; constructing of the problem directed graph based on a CCS-polytope skeleton graph with arcs corresponding to the function decreasing; a polynomial algorithm choice for solving the problem on partially ordered vertices

The Scalability Analysis of a Parallel Tree Search Algorithm

Roman Kolpakov[1], **Mikhail Posypkin**[2]

[1] *Moscow State University, Russia;* foroman@mail.ru
[2] *Dorodnicyn Computing Centre, FRC CSC RAS, Russia;*
mposypkin@gmail.com

Keywords: parallel scalability, parallel efficiency, complexity analysis, parallel tree search, global optimization

Increasing of the number of computational cores is a primary way of achieving high performance of contemporary supercomputers. However, developing of parallel applications capable to harness the enormous amount of cores is a challenging task. Thus, studying the scalability of parallel algorithms (the number of processors to be enlarged to accommodate the growing amount of work) is very important.

In this paper we propose a parallel tree search algorithm aimed at distributed parallel computers. For this parallel algorithm we perform a theoretical analysis of its scalability and show that the achieved scalability is close to the theoretical maximum.

Stochastic Flow on Manifolds

Nikola Konatar[1], **Darko Mitrovic**[2]

[1] *University of Montenegro, Faculty of Natural Sciences and Mathematics, Montenegro;* nikola.k@ac.me

[2] *University of Montenegro, Faculty of Natural Sciences and Mathematics, Montenegro;* darkom@ac.me

Keywords: conservation laws, stochastic, Cauchy problem, Riemannian manifold, well-posedness

We consider the scalar conservation law with stochastic forcing on a smooth, compact, d-dimensional Riemannian manifold (M,g), where the forcing W is a Wiener process. Assuming the flux function is a defines a vector field on M for each fixed real number, we introduce admissibility conditions, derive the kinetic formulation and use it to prove well posedness to the considered problem.

Frontier Visualization for Nonconvex Models with Increasing and Decreasing Returns to Scale with the Use of Enumeration Methods

Vladimir Krivonozhko[1], **Andrey Lychev**[2], **Nina Blokhina**[3]

[1] *National University of Science and Technology MISiS, Russia;* KrivonozhkoVE@mail.ru

[2] *National University of Science and Technology MISiS, Russia;* lychev@misis.ru

[3] *Moscow State University of Civil Engineering, Russia;* nsb_sapr@mail.ru

Keywords: free disposal hull, frontier visualization, enumeration methods

A lot of scientific literature in the world is devoted to the returns-to-scale (RTS) evaluation of production units. Kerstens and Vanden Eeckaut (1999) were the first who considered the notion and evaluation of RTS for nonconvex Free Disposal Hull (FDH) models. Their methods are based on the comparison of the radial efficiency scores of a production unit in the FDH model and the corresponding non-increasing and non-decreasing RTS reference models. At the same time Cesaroni, Kerstens and Van de Woestyne (2017) noted the absence of papers in the world literature devoted to methods of frontier visualization in nonconvex models. In this paper, we developed methods for visualization of production function of nonconvex models and of the corresponding non-increasing and non-decreasing models. Our approach of frontier visualization can be used for decision making based on nonconvex models. Our results are confirmed by computational experiments in applications with real-life data sets.

Cournot Oligopoly and a Berge Equilibrium

Konstantin Kudryavtsev[1], **Vladislav Zhukovskiy**[2]

[1] *South Ural State University, Russia;* kudrkn@gmail.com
[2] *M.V. Lomonosov Moscow State University, Russia;* zhkvlad@yandex.ru

Keywords: Cournot oligopoly, Berge equilibrium, Nash equilibrium, non-cooperative game

The first models of oligopolies were described more than a hundred years. Modeling of oligopolies continues to this day in many modern papers. The main approach meets the concept of the Nash equilibrium and is actively used in modeling the behavior of players in a competitive market.

The exact opposite of such selfish equilibrium is the altruistic concept of the Berge equilibrium. At the moment, many works are devoted to a Berge equilibrium. However, all of these items are limited to purely theoretical issues, or, in general, to psychological applications. Papers devoted to the study of Berge equilibrium in economic problems, were not seen until now. In this paper, the Berge equilibrium is considered in the Cournot oligopoly, and its relationship to the Nash equilibrium is studied. Cases are revealed in which players gain more profit by following the concept of the Berge equilibrium, than by using strategies dictated by the Nash equilibrium.

Problem of Deposit Diversification under Fuzzy Information

Konstantin Kudryavtsev[1], **Irina Stabulit**[2], **Viktor Ukhobotov**[3]

[1] *South Ural State University, Russia;* kudrkn@gmail.com
[2] *Chelyabinsk State University, Russia;* irisku76@mail.ru
[3] *Chelyabinsk State University, Russia;* ukh@csu.ru

Keywords: fuzzy information, decision making problem, Savage minimax regret criterion

In decision-making problems with fuzzy information, there are different concepts of solution. In this paper, a new concept is introduced, namely, "average solution". This concept can be used in combination with any classical criteria from decision theory.

In this paper, we use the average solution in conjunction with the Savage minimax regret criterion. As an example of a practical application, the problem of diversification of a two-currency deposit is suggested and solved. Here, the decision-maker should allocate his deposit in the bank taking into two currency deposits (in dollars and euro) for one year. But the cross rates of currencies at the end of the year is a fuzzy uncertainty.

Comparative Analysis of Heuristic Routing Algorithms Depending on the Network Topology of the Network Graph

Ilya Kurochkin[1], **Yakov Grinberg**[2], **Alexandra Prun**[3]

[1] *IITP RAS, Russia;* qurochkin@gmail.com
[2] *IITP RAS, Russia;* greenjak@iitp.ru
[3] *IITP RAS, Russia;* aiprun@iitp.ru

Keywords: Telecommunication network, rational use of network resources, network topology, jellyfish, dragonfly, multicommodity problem, minimal cost path algorithm

An mathematical simulation model of the functioning of the telecommunications network was created. Within the simulation model, a sequential laying of paths on the network graph between different pairs of nodes is carried out according to various criteria. The article presents several approaches to the formation of criteria for laying paths on the network graph, as well as criteria and algorithms. The creation of a set of test networks of certain network topologies, such as jellyfish, dragonfly and fattree, is discussed. Based on the simulation results, a comparative analysis of various pathway algorithms taking into account the network topology is carried out. The results of the work of various algorithms are evaluated not only by the principle of maximizing the total conducted flow in the network, but other indicators are also taken into account.

Variational Principle of Biology Based on Measure Dynamics

Oleg Kuzenkov[1]

[1] *Lobachevsky State University of Nizhni Novgorod, Russia;*
kuzenkov_o@mail.ru

Keywords: variational principles, measure dynamics, evolutionary fitness, behavior, selection

Currently, variational principles are often used for mathematical modeling of biological phenomena. They allow predicting the evolutionarily stable behavior, as the movement of mechanical systems is derived on the basis of the Euler-Lagrange principles. The principles are the implementation of the seminal Darwin's idea Survival of the fittest' and uses the maximisation of some criterion fitness function. However, the concept of the evolutionary fitness is still somewhat vague, intuitive and is often subjective. As a result, one can predict conflicting evolutionary outcomes. In this work a novel axiomatic approach is developed for modeling selection processes. For a generic self-replication system, the ranking order of inherited units is introduced on the base of measure density dynamics. Using this ranking, it is possible to derive a generalized fitness function.

Minimization of the Weighted Total Sparsity of Cosmonaut Training Courses

Alexander Lazarev[1], Nail Khusnullin[2], Elena Musatova[3], Denis Yadrentsev[4], Maxim Kharlamov[5], Konstantin Ponomarev[6]

[1] *V.A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, Russia;* jobmath@mail.ru

[2] *V.A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, Russia;* nhusnullin@gmail.com

[3] *V.A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, Russia;* nekolyap@mail.ru

[4] *Yu.A. Gagarin Research & Test Cosmonaut Training Center, Russia;* d.yadrentsev@gctc.ru

[5] *Yu.A. Gagarin Research & Test Cosmonaut Training Center, Russia;* m.kharlamov@gctc.ru

[6] *Yu.A. Gagarin Research & Test Cosmonaut Training Center, Russia;* k.ponomarev@gctc.ru

Keywords: resource-constrained project scheduling problem, heuristic method, optimization, non-regular objective function

The paper is devoted to a cosmonaut training planning problem, which is a generalization of the resource-constrained project scheduling problem (RCPSP). Training of each cosmonaut is divided into special courses. To avoid too sparse courses, we introduce a special objective function – the weighted total sparsity of training courses. This non-regular objective function makes the problem harder to solve than the thoroughly studied RCPSP with the makespan criterion. A new heuristic algorithms for solving this problem are proposed. Their efficiency is verified on real-life data.

Heuristic Algorithm for the Bi-Level Facility Location and Design Problem

Tatyana Levanova[1], **Stanislav Belan**[2]

[1] *Sobolev Institute of Mathematics SB RAS, Omsk Branch, Russia;*
levanova@ofim.oscsbras.ru

[2] *Dostoevsky Omsk State University, Russia;*
belan.stanislav.rfbr@gmail.com

Keywords: location problem, bi-level programming, elastic demand, heuristic, variable neighborhood search

The bi-level location problem with elastic demand is considered. Two rivals, the Leader and the Competitor, are fighting for the customers' demand in order to maximize their market share. Clients distribute their own demand probabilistically over all the opened facilities by the so called gravity rule. The service structure varies flexibly depending on the location and design of the facility being opened. The Leader's task is to maximize its own market share taking into account the Competitor's reaction. This problem can be presented by the nonlinear 01 bi-level optimization model. The elastic demand is described by an exponent and is included in the goal function. In this form the bi-level model is considered for the first time. The decision methods are developed in this report. The variant of an alternative algorithm is proposed. Some heuristics, including the variable neighborhood search, are used for this purpose. The results of the numerical experiments are discussed.

Parallel Application for Works Distribution in Hierarchic Systems

Sergey Lupin[1], **Sai Win Maw**[2], **Aye Min Thike**[3]

[1] *National Research University of Electronic Technology, Moscow, Russia, Russia;* papikam@rambler.ru

[2] *National Research University of Electronic Technology, Moscow, Russia, Russia;* saiwinmaw50@gmail.com

[3] *National Research University of Electronic Technology, Moscow, Russia, Russia;* ayeminthike52@gmail.com

Keywords: Hierarchical system, Works distribution algorithm, Parallel implementation of algorithm

In this paper presented a parallel application realizing brute force method for solving the optimization task - work's distribution between nodes of hierarchical systems. Three levels hierarchic structure has been used as an example for investigation the scalability of the algorithm's parallel implementation. Computation results on three different processors including Intel Xeon Phi accelerator show that parallel application demonstrate good level of scalability and efficiency.

The Lemke-Howson Algorithm Solving Finite Non-Cooperative Three-Persons Games in a Special Setting

Ustav Malkov[1], **Nikolay Sokolov**[2]

[1] *CEMI RAN, Russia;* ustav-malkov@yandex.ru
[2] *CEMI RAS, Russia;* sokolov_nick@rambler.ru

Keywords: a non-coalition game, Nash point, pure strategy, mixed strategy, approximate method, Lemke-Howson method, numerical testing, linear programming

A brief description of the approximate method of solving finite noncooperative three persons games in mixed strategies (3LP algorithm) proposed by E. G. Golstein is given. Finding a solution to the game boils down to minimizing the so-called Nash functions, which have a large number of local minima. It was possible to adapt the method of Lemke-Howson, successfully solving bimatrix games, also for case of three-person game in the private (hexamatrix) setting (proposed by A.S. Strekalovsky). Numerical testing of the method was carried out, revealing its advantages and disadvantages.

Continuous Speech Recognition of Kazakh Language

Orken Mamyrbayev[1], Mussa Turdalyuly[2], Nurbapa Mekebayev[3], Kuralay Mukhsina[4], Alimkhan Keylan[5], Bagher Babaali[6], Gulnaz Nabieva[7], Yergali Dauletbek[8]

[1] *Institute of Information and Computational Technologies, Kazakhstan;* morkenj@mail.ru

[2] *Institute of Information and Computational Technologies, Kazakhstan;* mkt_001@mail.ru

[3] *Institute of Information and Computational Technologies, Kazakhstan;* nurbapa@mail.ru

[4] *Institute of Information and Computational Technologies, Kazakhstan;* kuka_ai@mail.ru

[5] *Institute of Information and Computational Technologies, Kazakhstan;* Keylan@live.jp

[6] *Institute of Information and Computational Technologies, Kazakhstan;* bagher.babaali@gmail.com

[7] *Institute of Information and Computational Technologies, Kazakhstan;* gulnaz_nc@mail.ru

[8] *Institute of Information and Computational Technologies, Kazakhstan;* dauletbekyergali2011@gmail.com

Keywords: Speech recognition, low-resource languages, body of Kazakh language, continuous speech, deep neural networks

This article describes the methods of creating a system of recognizing the continuous speech of Kazakh language. Studies on recognition of Kazakh speech in comparison with other languages began relatively recently, that is after obtaining independence of the country, and belongs to low resource languages. A large amount of data is required to create a reliable system and evaluate it accurately. A database has been created for the Kazakh language, consisting of a speech signal and corresponding transcriptions. The continuous speech has been composed of 200 speakers of different genders and ages, and the pronunciation vocabulary of the selected language. Traditional models and deep neural networks have been used to train the system. As a result, a word error rate (WER) of 30.01% has been obtained.

Network Partitioning Algorithm Based on Myerson Value

Vladimir Mazalov[1]

[1] *Institute of Applied Mathematical Research, Karelian Research Center, Russia;* vmazalov@krc.karelia.ru

Keywords: network partitioning, cooperative game, Myerson value, stable partition

Community detection in networks is a very important problem in many fields of applications: in biological communities, social networks, communications. Here we propose to use the methods of cooperative game theory that emphasize the mechanisms of cluster formation. A cooperative game related with network structure is formed and then we find the stable partition of the network into coalitions from the nodes. Our approach is based on the Myerson value. The payoff of a player depends on the number of paths passing through a given vertex and it is determined as the Myerson value. For current partition of the community each player compares the payoff inside his coalition and expected payoff in case of deviating. The result of community detection is a stable partition where for any player it is not beneficial to join to another coalition. We propose the algorithm which implements this approach. The results of computer simulations for different communication networks are presented.

Revisiting the Implementation of the Decomposition Algorithm for Solving One Class of Discrete Optimization Problems with a Semidefinite Relaxation

Yurii A. Mezentsev[1], **Pavel S. Pavlov**[2]

[1] *Novosibirsk State Technical University, Russia;* mesyan@yandex.ru
[2] *Novosibirsk State Technical University, Russia;*
pavlov.pavel.sergeevich@gmail.com

Keywords: Mixed Discrete Optimization Problem, Semidefinite Relaxation, Selection of Suppliers, Determination of Prices

A universal mathematical economic model is discussed, which is designed to find optimal strategies for controlling the logistics subsystems (subsystem components) of a company. An approximate efficient algorithm is proposed for solving optimization problems of actual dimension, characterized by high computational complexity.

The object of control is a company whose main activity is wholesale and retail trade. In-house production is also possible, but production departments are subordinate to sales ones. The control actions include the selection of suppliers, determination of procurement volumes for all items in the product line, and determination of prices and sales volumes.

Numerical Damping of Forced Oscillations of an Elastic Beams

Igor Mikhailov[1], **Andrey Atamuratov**[2], **Nikolay Taran**[3]

[1] *FRC IC RAS, Russia;* mikh_igor@mail.ru
[2] *PPK Ltd, Russia;* goofydog@mail.ru
[3] *Moscow Aviation Institute, Russia;* n1ckolaytaran@gmail.com

Keywords: Oscillations damping, Fixed point actuators, Matrix sweep method, Marquardt minimization method

The beam oscillations are modeling by the fourth-order hyperbolic partial differential equation. The minimized functional is the energy integral of an oscillating beam. Control is implemented via certain function appearing in the right side of the equation. It was shown that the solution exists for any given time. The numerical damping of beam oscillations is implemented via several fixed point actuators. Computational algorithms have been developed on the basis of the matrix sweep method and the second order Marquardt minimization method. To find a good initial approximation, when minimizing the energy integral, empirical functions with a small number of variables are used. Examples of damping the oscillations in the presence of constraints on control functions are given; in this case the minimum damping time exists. The damping of oscillations is considered also in the case when different combinations of actuators are switched on at different time intervals of oscillation damping.

On the Choice of Optimal Parameters in a Class of Mechanical Systems

Arsalan Mizhidon[1], **Klara Mizhidon**[2]

[1] *East Siberia State University of Technology and Management, Russia;*
miarsdu@mail.ru

[2] *East Siberia State University of Technology and Management, Russia;*
migka@mail.ru

Keywords: hybrid system of differential equations, rod, optimal parameters

In report we discuss a hybrid system of differential equations that describes a class of mechanical systems that are a system of solids connected to an elastic rod. For this class of mechanical systems, some optimization problems of choosing optimal parameters are considered.

On One Approach to Solving the Control Problem with Phase Constraints

Klara Mizhidon[1]

[1] *East Siberia State University of Technology and Management, Russia;*
migka@mail.ru

Keywords: control, state constraints, polyharmonic disturbance, weight coefficient, mean square functional

We consider the problem of control for linear dynamic system under given perturbations. In this problem the main purpose of control is to keep the system in the state constraints. Here the constraints are imposed on control. We consider an auxiliary optimal control problem with quadratic performance measure and system matrices depending on weight coefficients. The choice of these coefficients provides satisfaction of the state constraints.

Possibility to Use the Results of Mathematical Modeling for Clarifying the Diagnosis in Glaucoma

Irina Moiseeva[1], **Alexander Stein**[2], **Gregory Lyubimov**[3]

[1] *Institute of Mechanics, Moscow State University, Russia;* moiseeva.ir@yandex.ru

[2] *Institute of Mechanics, Moscow State University, Russia;* stein.msu@bk.ru

[3] *Institute of Mechanics, Moscow State University, Russia;*

Keywords: Mathematical model, tonometry, glaucoma

The aim of the study was to find and justify some characteristics that can be determined in standard ophthalmologic tests and correlate with the data on glaucoma progression degree for the eye investigated. The analysis is based on the results we have obtained by simulating tonometric measurements with Maklakoff and Schiotz tonometers using our mathematical model of the eyeball.

The results testify in favor of the contemporary hypothesis about the correlation between glaucoma severity and the level of abnormality of elastic properties of the corneoscleral coat. It is shown that the progress of the disease is accompanied by increase in the Schiotz pressure difference coefficient and decrease in the similar Maklakoff coefficient. An important additional characteristic, the ratio of these coefficients, is proposed. Increase in this ratio with glaucoma progression corresponds to increase in scleral stiffness simultaneously with a more significant increase in the stiffness of the cornea.

Research and Development of Models for Modular Data Processing Systems of Various Classes and Purposes

Gulnaz Nabiyeva[1], Sultan Akhmetov[2], Aliya Kalizhanova[3], Lyazzat Balgabayeva[4], Timur Kartbayev[5], Aliya Doszhanova[6]

[1] *Almaty University of Power Engineering and Telecommunications, Kazakhstan;* gulnaz_nc@mail.ru

[2] *Almaty University of Power Engineering and Telecommunications, Kazakhstan;* as_sultan@mail.ru

[3] *Institute Information and Computational Technologies CS MES RK, Kazakhstan;* kalizhanova_aliya@mail.ru

[4] *Turan University, Kazakhstan;* lyazzat_iso@mail.ru

[5] *Almaty University of Power Engineering and Telecommunications, Kazakhstan;* kartbaev_t@mail.ru

[6] *Almaty University of Power Engineering and Telecommunications, Kazakhstan;* d_alia.81@mail.ru

Keywords: Data processing systems, methods of designing, application programs, information elements

Abstract. This work is devoted to research and development of data processing systems. Data processing systems (DPS) of various classes and purposes are represented by the collection of applied software, databases, system-wide software, implemented on the basis of the computer system, with the purpose of getting the objectives of some practical application for data processing or control. The main objectives of designing the data processing system are the synthesis of the application software and database, while they are still developed, often using the experience and knowledge of specific developers.

Modified Duality Method for Solving an Elastic Problem with a Crack Extending to the Outer Boundary

Robert Namm[1], **Georgiy Tsoy**[2], **Elinna Vikhtenko**[3]

[1] *CC FEB RAS, Russia;* rnamm@yandex.ru

[2] *CC FEB RAS, Russia;* tsoy.dv@mail.ru

[3] *Pacific National University, Russia;* vikht.el@gmail.com

Keywords: non-penetration condition, crack, duality scheme, modified Lagrange functional, generalized Newton method

A modified dual method for solving an elastic problem with a crack extending to the outer boundary is considered. The method is based on a modified Lagrange functional. The convergence of the method is investigated in detail under a natural assumption of H^1-regularity of the solution to the crack problem. Basic duality relation for the primal and dual problems is proposed.

A Software System for Acceptability Region Construction and Optimal Parametric Synthesis

Dmitry Nazarov[1], **Oleg Abramov**[2]

[1] *Institute of Automation and Control Processes, FEB RAS, Russia;* nazardim@iacp.dvo.ru

[2] *Institute of automation and control processes, Russia;* abramov@iacp.dvo.ru

Keywords: reliability, optimal parametric synthesis, acceptability region, computer-aided design

The paper describes a software system for acceptability regions determinatation, construction, analysis and using during engineering systems design. In general, acceptability region is a set of points inside system parameters space, yielding system performances which meet their specifications. Acceptability regions are usually used for optimal parametric synthesis both using stochastic, and deterministic criteria. Obtaining characteristics of the region also facilitates the exploration of parametric deviations influence at system performance. The main challenges of acceptability region determination and its exploitation consist in high dimensionality and lack of explicit analytical expressions of system model due to using various CAD facilities and simulation software which implement the concept of a "black box" and allow only point-wise exploration of parameter space. This work describes components of the software system and their interaction.

Primal-Dual Accelerated Gradient Descent with Line Search for Convex and Nonconvex Optimization Problems

Yurii Nesterov[1], **Alexander Gasnikov**[2], **Sergey Guminov**[3], **Pavel Dvurechensky**[4]

[1] *Center for Operations Research and Econometrics, UCL; National Research University Higher School of Economics, Belgium;*

[2] *Moscow Institute of Physics and Technology, Russia;*

[3] *Moscow Institute of Physics and Technology, Russia;*

sergey.guminov@phystech.edu

[4] *Weierstrass Institute for Applied Analysis and Stochastics, Germany;*

Keywords: Accelerated gradient descent, Line-search, Primal-dual methods

A new variant of accelerated gradient descent is proposed. The proposed method does not require any information about the objective function, uses exact line search for practical accelerations of convergence, converges according to the well-known lower bounds for both convex and non-convex objective functions, possesses primal-dual properties and can be applied in the non-euclidian set-up. As far as we know, this is the first method possessing all of the above properties at the same time. We demonstrate how in practice one can efficiently use the combination of line-search and primal-duality by considering a convex optimization problem with a simple structure. Numerical experiments show that the method may perform well in practice, particularly on non-smooth problems, non-convex problems, and the problem of entropy-linear programming.

Vertex Adjacencies in the Polytope of Pyramidal Tours with Step-Backs

Andrei Nikolaev[1]

[1] *P.G. Demidov Yaroslavl State University, Russia;*
andrei.v.nikolaev@gmail.com

Keywords: pyramidal tours with step-backs, polyhedral combinatorics, 1-skeleton, vertex adjacency

The traveling salesperson problem is the problem of finding a shortest Hamiltonian cycle in a graph. We consider a special class of Hamiltonian cycles: pyramidal tours with step-backs, described by Enomoto, Oda and Ota. It is known that the traveling salesperson problem is NP-hard, while a minimum cost pyramidal tour with step-backs can be determined in polynomial time by dynamic programming.

We construct the traveling salesperson polytope TSP(n) and the polytope of pyramidal tours with step-backs $PSB(n)$ as the convex hulls of characteristic vectors of all corresponding tours in the complete graph on n vertices. The 1-skeleton of the polytope P is the graph whose vertex set is the vertex set of P and edge set is the set of 1-faces of P. It is known that the question whether two vertices of $TSP(n)$ are nonadjacent is NP-complete. We describe the algorithm that verify the vertex adjacency in $PSB(n)$ skeleton in linear time $O(n)$.

Projection Problems and Algorithms

Evgeni Nurminski[1]

[1] *Far Eastern Federal University, Russia;* nurminskiy.ea@dvfu.ru

Keywords: convex optimization, projection, polytope, decomposition

The aim of this talk is to review some questions related to projection or least-norm problems which constitute major computational steps of many optimization algorithms.

The following topics are considered: projection on polyhedral sets in inner and outer representation, relation to supporting or separating problems, mixed inner-outer projection problems, decomposition approaches for projection problems.

Locally Constant Model Uncertainty Risk Measure

Lazar Obradovic[1]

[1] *University of Montenegro, Montenegro;* lazaro@ac.me

Keywords: risk measure, coherent risk measure, optimal portfolio, Merton portfolio

This paper introduces a (coherent) risk measure that describes the uncertainty of the model (represented by a probability measure P_0) by a set P_λ of probability measures each of which has a Radon-Nikodym's derivative (with respect to P_0) that lies within the interval $[\lambda, \frac{1}{\lambda}]$ for some constant $\lambda \in (0, 1]$. Economic considerations are discussed and an explicit representation is obtained that gives a connection to both the expected loss of the financial position and its Average Value-at-Risk. Optimal portfolio analysis is performed – different optimization criteria lead to Merton portfolio. Comparison with related problems reveals examples of extreme sensitivity of optimal portfolios to model parameters and the choice of risk measure.

A Model of Economic Growth with Consumer Optimization and a Given Age Limit for Production Capacity

Nicholas Olenev[1]

[1] *Doronicyn Computing Centre FRC CSC RAS, Russia;* nolenev@mail.ru

Keywords: economic growth, consumer optimization, aggregated production function, production capacity, numerical solution, Russian economy

A model of economic growth with consumer optimization (Ramsey model) is considered. A new aggregated production function is used with a given production age limit. The optimal control problem with mixed constraints is posed. The share of new capacities acts a control variable. A numerical solution of this problem was found for the parameters of the production function, identified by statistical data of the Russian economy 1970-2017.

On Convergence Rates of CGM and ECGM Algorithms

Omolehin Joseph Olorunju[1]

[1] *Federal Univerity Lokoja, Nigeria;* jomolehin@gmail.com

Keywords: Reaction diffusion, Convergence, Operator, CGM, ECGM

The work considers a new estimate for the convergence rates of Conjugate Gradient Method (CGM) and the Extended Gradient Method (ECGM) algorithms.

Recall the convergence rates of the CGM and ECGM algorithms were based on the associated matrix operators. This this work is based on the spectrum analysis of the associated control operator in the Control Functional and some properties of the conventional rates.

This new versions of convergence rates of CGM and ECGM algorithms are favorably comparable with conventional rates of convergence.

The Calculation of Stratospheric Aerosol Sources Optimal Distribution for Climate Stabilization

Valeriy Parkhomenko[1]

[1] *Dorodnicyn Computing Centre, FRC CSC RAS; Bauman Moscow State Technical University, Russia;* vparhom@yandex.ru

Keywords: global climate modeling, climate warming, aerosol emissions

Global warming climate changes are observed in recent decades. These changes largely associated with anthropogenic increases in greenhouse gases in the atmosphere (CO2 most important among them). The problem and opportunity of the global climate stabilization at a current level were investigated early. The current study is based on a three-dimensional hydrodynamic global climate coupled model, including ocean model with real depths and continents configuration, sea ice evolution model and atmospheric general circulation model. Aerosol concentration from the 2010 up to 2100 year is calculated as a controlling parameter to stabilize mean year surface air temperature. It is investigated opportunity to get prescribed space and time global distribution of the stratosphere aerosol when exist limited number of aerosol sources. Wind transport and deposition of aerosol are taken into account.

On Optimal Selection of Coefficients of Path Following Controller for a Wheeled Robot with Constrained Control

Alexander Pesterev[1]

[1] *Institute of Control Sciences, Russia;* a.pesterev@javad.com

Keywords: wheeled robot, path following problem, saturated control, feedback linearization, optimal path following controller

The problem of stabilizing motion of a wheeled robot along a target path (the path following problem) is considered. The problem is solved by the feedback linearization technique, in the framework of which the system is linearized by applying an appropriate nonlinear feedback. When the control resource is constrained, linearization in the entire space is impossible. By applying the saturation function to the linearizing control law to meet the constraints, we get the closed-loop system that is linear in a neighborhood of the origin and nonlinear outside it. We pose the problem of finding coefficients of the linearizing feedback that optimize the system performance. The optimality is meant in the sense that the phase portrait of the closed-loop system is topologically similar to that of the corresponding linear system, with the asymptotic rate of decrease of the deviation from the target path being as high as possible. The discussion is illustrated by numerical examples.

Oscillations Control in Nonlinear Dynamical Systems

Lev Petrov[1]

[1] *Plekhanov Russian University of Economics, Russia;* lfp@mail.ru

Keywords: Oscillations control, Nonlinear dynamical systems, Evolution of solutions

Control of stationary oscillations in nonlinear dynamic systems is considered. To find periodic solutions of corresponding ordinary differential equation systems, an interactive algorithm is used, based on minimizing the solution deviation from the periodic form. The possibility the system behavior controlling due to the mutual nonlinear influence of various types of oscillations is considered. For nonlinear dynamical systems with one and several degrees of freedom,examples of various types oscillations control are given.

Some Models of Tool Path Optimization Problem for Sheet Metal Cutting Machines

Alexander Petunin[1], **Pavel Chentsov**[2], **Evgeny Ivanko**[3]

[1] *Ural Federal University, Russia;* a.a.petunin@urfu.ru

[2] *Institute of mathematics and mechanics, Ural branch, Russian Academy of Sciences, Russia;* chentsov.p@mail.ru

[3] *Institute of mathematics and mechanics, Ural branch, Russian Academy of Sciences, Russia;* viatore@ya.ru

Keywords: Sheet metal cutting machines, Tool path problem, NC programs, technological constraints, discrete optimization, TSP, GTSP, dynamic programming

We consider a problem of cutter head path optimization for the computer numerical control (CNC) sheet metal cutting equipment. Time of cutting and cost of cutting are the main optimization criteria in the tool path optimization problem arising during the process of development of numerical control programs. In the paper we offer an approach for reducing some classes of the tool path problem to a special case of the generalized traveling salesman problem (GTSP) with additional constraints. The resulting GTSP problem can be solved using both a special scheme of dynamic programming and heuristic algorithms. One of the contributions of this paper is the method allowing to reduce the tool path problems that do not include embedded contours and allow partial cutting to the TSP with a special distance matrix. Results of computing experiments for some instances are given.

Mathematical Formalization and "Dynamic" Constraints of the Tool Path Problem for the CNC Cutting Machines

Alexander Petunin[1]

[1] *Ural Federal University, Russia;* a.a.petunin@urfu.ru

Keywords: Tool path problem, CNC cutting machines, sheet metal, the basic cutting segment, optimization models of routing, GTSP with constraints, "dynamic" constraints

Tool path problem for the CNC sheet metal cutting machines is consider. On the basis of the entered concept of a basic cutting segment the new class of tasks within the considered problem is defined. Mathematical formalization of such tasks in the form of continuous-discrete optimization problem is given. It is shown that the formulated task can be reduced to a finite set of problems of combinatory optimization (GTSP) with additional difficult constraints. The definition of the "dynamic" (changing) constraints for GTSP is given. Such kind of constraints is arising by thermal cutting of sheet metal. Some algorithms for the solution of GTSP with offered "dynamic" constraints is described. Results of some computing experiments are given.

The Euclidean Combinatorial Configurations: Modeling and Optimization

Oksana Pichugina[1], **Sergey Yakovlev**[2]

[1] *National Aerospace University "Kharkv Aviation Institute", Ukraine;*
oksanapichugina1@gmail.com

[2] *National Aerospace University "Kharkv Aviation Institute", Ukraine;*
svsyak7@gmail.com

Keywords: Combinatorial optimization, Euclidean combinatorial configuration, Continuous functional representation, Convex extension, Permutation set, Boolean set

In this paper, we introduce a concept of Euclidean combinatorial configuration as a mapping of a set of certain objects into a point of Euclidean space. We classify Euclidean combinatorial configurations sets based on their structure and constraints. The paper presents general approaches to continuous representations of the classes of sets. Classes of vertex-located and polyhedral-spherical configuration sets such as the Euclidean permutation configurations set and Boolean set have been formalized, with due regard to their properties. We also focus on the behavior of functions determined on vertex-located configurations. We study the optimization problem over vertex-located sets of Euclidean configurations and offer its equivalent formulation with convex both objective function and functional constraints.

The Model of the Russian Banking System with Indicators Nominated in Rubles and in Foreign Currency

Nikolay Pilnik[1], **Stanislav Radionov**[2], **Artem Yazikov**[3]

[1] *Higher School of Economics, Russia;* u4d@yandex.ru
[2] *Higher School of Economics, Russia;* saradionov@edu.hse.ru
[3] *Higher School of Economics, Russia;* ayazikov@hse.ru

Keywords: Banking system, optimal control, complementary slackness conditions

We propose a model of the Russian banking system. It is based on the problem of a macroeconomic agent "bank" which is modeled according to the principles of aggregated description, optimality and perfect foresight. To derive the equations of the model, we use the original method of relaxation of complementary slackness conditions. The model successfully reproduces main indicators of the banking system, such as total loans, deposits, settlement accounts, reserves and profits nominated both in rubles and in foreign currency.

Genetic Local Search for Conflict-Free Minimum-Latency Aggregation Scheduling in Wireless Sensor Networks

Roman Plotnikov[1], **Adil Erzin**[2], **Vyacheslav Zalyubovskiy**[3]

[1] *Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences, Russia;* prv@math.nsc.ru

[2] *Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences, Russia;* adilerzin@math.nsc.ru

[3] *Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences, Russia;* slava@math.nsc.ru

Keywords: wireless sensor networks, aggregation, minimum latency, genetic local search, simulation

We consider a Minimum-Latency Aggregation Scheduling problem in wireless sensor networks when aggregated data from all sensors is required to be transferred to the base station (BS). During one time slot (time is discrete) each sensor can either send or receive one message. Moreover, only one message should be sent by each sensor during the aggregation session, and the conflicts caused by interference of radio waves must be excluded. It is required to find a min-length conflict-free schedule for transmitting messages along the arcs of the desired spanning aggregation tree (AT) with the root in BS. This problem is NP-hard in general case, and also remains NP-hard in a case when AT is given. In this paper we present a new heuristic algorithm that uses genetic algorithm and contains the local search procedures and a randomized mutation procedure. Extensive simulation demonstrates significant superiority of our algorithm over the best of the previous approaches.

The Network Stochastic Model for Choosing an Effective Implementation of a Resource Megaproject

Nina Plyaskina[1]

[1] *Institute of Economics and Industrial Engineering of SB RAS, Novosibirsk State University, Novosibirsk, Russia, Russia;* pliaskina@hotmail.com

Keywords: network stochastic model, optimization problem, resource schedule

The report proposes a solution to the problem of choosing an effective implementation of a resource megaproject based on a network stochastic model. The task is presented as the task of optimizing resource scheduling in alternative variants of performance of works with different probabilities. The algorithm of the statistical drawing of scheduling and the formation of the investment program is proposed.

As a result of the branching of the algorithm, we obtain a family of deterministic network models. The implementation of the model with the maximum profit per unit of investment is chosen for given target dates and limited resources. The proposed algorithm is implemented on the real economic information of the mega-project of the East Siberian Oil and Gas Complex, 20 realizations of the stochastic network model are carried out. The schedule for the implementation of the megaproject investment program and the distribution histogram are constructed.

Local and Global Convergence of Frank-Wolfe Nethod on Stiefel Manifolds for Non-Convex Functions

Boris Polyak[1], **Andrey Tremba**[2]

[1] *Institute of Control Sciences, Russia;* boris@ipu.ru
[2] *Institute of Control Sciences, Russia;* atremba@ipu.ru

Keywords: Frank-Wolfe method, Stiefel manifold, non-convex optimization

We explore a modification of the famous Frank-Wolfe method for smooth optimization on non-convex sets. There are no line-search rules for step-size choice; moreover, the objective function may be non-convex as well.

We consider two classes of such problems: optimization on a sphere in Euclidian space and matrix optimization on the set of orthonormal matrices. Under strict assumptions global convergence is proved; weaker assumptions imply local convergence.

The Relation Between Various Mathematical Principles of Investment Portfolio Selection

Leonid Popov[1]

[1] *Inst. of Mathematica and Mechanics UB RAS, Russia;* popld@imm.uran.ru

Keywords: quadratic programming, investment portfolio, Markowitz model, VaR-criterion, probability of bankruptcy

In this report, we discuss a correlation between modern criteria for investment portfolio problem (optimization of mathematical expectation at a given threshold for the probability of mismanagement, the VaR criterion, etc.) with the very first ones proposed by Markowitz in his seminal work. As an illustration of the general approach, we give formulas for a simple estimate of such a risk, obtained under the assumption of the passivity of a number of constraints in its classical model. The formulas are accompanied by test and real examples of applications.

Usage of SDP Relaxation in Some GNSS Navigation Problems

Lev Rapoport[1]

[1] *V.A. Trapeznikov Institute of control sciences RAS, Russia;*
LBRapoport@gmail.com

Keywords: SDP relaxation, GNSS navigation, convex programming

In this paper we present a novel approach to solution of some satellite navigation problems. First one consists in attitude determination using carrier phase and code range observables measured by multiple antennas, total number greater or equal to three. Second problem consists in optimization of the set of the satellites signals chosen for processing. It is the binary optimization problem. We show how these problems can be reduced to the semidefinite programming problem (SDP) and therefore efficiently solved. The SDP relaxation approach became popular in control and system theory for last two decades. Within this approach the linear function is minimized over the convex set formed by linear matrix inequalities(LMI). The convex SDP relaxation assumes substitution of the original nonlinear problem with the SDP optimization problem, probably having wider set of constraints, but convex and therefore assuming numerical tractability.

Synthesis of Parallel Robots Optimal Motion Trajectory Planning Algorithms

Larisa Rybak[1], **Dmitry Malyshev**[2], **Sergey Khalapyan**[3], **Viktoria Kuzmina**[4]

[1] *BSTU named after V. G. Shoukhov, Russia;* rl_bgtu@intbel.ru
[2] *BSTU named after V. G. Shoukhov, Russia;* malyshev_d.i@yandex.ru
[3] *Stary Oskol Technological Institute (Branch) N.a. A.A. Ugarov NUST MISiS, Russia;* khalapyan@yandex.ru
[4] *BSTU named after V. G. Shoukhov, Russia;* gaponenkobel@gmail.com

Keywords: working area, planar robot, trajectory optimization

The article considers the problem of planning the optimal trajectory of the tripod robot movement. The movement of the output link includes working displacements that are performed for the purpose of machining the workpiece and are completely determined by the surface of the workpiece, as well as the movement of the tool to the beginning of the next stage of processing, which can be relatively free, however, taking into account working area and workpiece surface limitations. The working area is limited by the range of permissible lengths of the drive links and the sign of the Jacobian. Additional restrictions are introduced, related to the dimensions of the workpiece. Chebyshev's metric makes a significant ambiguity in the choice of the trajectory. Therefore, it is proposed to supplement the original objective function with the Euclidean metric taken with a small weighting factor. Optimization was carried out with restrictions on the size of the working space and workpiece.

One General Branch-and-Bound Scheme for Dynamic Programming in Precedence-Constrained Traveling Salesman

Yaroslav Salii[1]

[1] *IMM UrB RAS; UrFU, Russia;* yvs314@gmail.com

Keywords: precedence constraints, traveling salesman, dynamic programming, metaheuristics, branch-and-bound

The precedence constrained traveling salesman problem (TSP-PC) consists of finding an optimal TSP tour that satisfies the namesake constraints.

Dynamic programming (DP) is one its solution method, viable for "heavily constrained" problem instances; we "extend" it to less constrained instances through a MorinMarsten branch-and-bound scheme that inherits the abstract travel cost aggregation feature of the DP, which permits its usage with both the ordinary and bottleneck (min-max instead of min-sum) versions of TSP-PC.

This scheme prunes the DP state graph based on some feasible solution and a lower bound heuristic. The former will be obtained through the restricted DP heuristic in abstract aggregation form, which could produce good upper bounds for "heavily" and "medium"-constrained instances; the latter through an abstract aggregation version of shortest path that would also be precedence-aware. The scheme will then be tested on TSPLIB instances, in ordinary and bottleneck forms.

The Space-Time Representation for Optimal Impulsive Control Problems with Hysteresis

Olga N. Samsonyuk[1]

[1] *Matrosov Institute for System Dynamics and Control Theory of SB RAS, Russia;* samsonyuk.olga@gmail.com

Keywords: Measure-driven differential equation, Sweeping process, Rate independent hysteresis, Impulsive control, Space-time representation, Optimal control

An optimal control problem over a sweeping process driven by impulsive controls is considered. The control system we study is described by both a measure-driven differential equation and a differential inclusion. This system is the impulsive-trajectory relaxation of an ordinary control system with nonlinearity of hysteresis type, in which the hysteresis is modeled by the play operator and considered as a particular case of nonconvex sweeping process. The concept of sweeping process for the so-called graph completions of functions of bounded variation, defining the corresponding moving set, is developed. The space-time representation based on the singular space-time transformation and a method to obtain optimality conditions for impulsive processes are proposed. By way of motivation, an example from mathematical economics is considered.

Sequential Optimal Controls and Its Structure

Simon Serovajsky[1]

[1] *al-Farabi Kazakh national university, Kazakhstan;* simon.serovajsky@bk.ru

Keywords: optimal control, minimizing sequence, sequential method, extension

The optimal control problem can be insolvable. However, there exists minimizing sequences for it. We would like to determine the method of finding it.

Let us have the minimization problem for the functional I on the set U. Consider the set F of the sequences $\{uk\}$ of U such that the sequence $\{I(uk)\}$. Two sequences of F are equivalent if it have the same limit of the functional sequences. The corresponding factor-set V is called the set of sequential control. Determine the functional J on V by the formula $J(v) = \lim I(uk)$, where $\{uk\}$ is an arbitrary sequence of F that determine the sequential control v.

The sequential control v minimizes the functional J on the set V if each sequence of F that determine v is minimizing for the functional I on the set U, besides $\min J(V) = \inf I(U)$. The minimization problem for J is solvable. It give the method of finding minimizing sequences for the initial problem. We consider examples.

On Clustering Method for VANET Efficiency Improvement

Vladimir Shakhov[1], **Olga Sokolova**[2]

[1] *Institute of Computational Mathematics and Mathematical Geophysics, Russia;* vladimir.shakhov@gmail.com

[2] *Institute of Computational Mathematics and Mathematical Geophysics, Russia;* olga@rav.sscc.ru

Keywords: Optimization problems, data transmission problems, clustering

Quality of service and efficiency improvement is an important problem of modern networks, such as Vehicle ad-hoc networks (VANET). The current trend in research and development of technologies for increasing the efficiency of VANET is as follows: clustering methods, utilization of the capabilities of base stations (LTE technology), vehicle-to-road communication. A clustering method can essentially increase the efficiency of short messages dissemination between vehicles. The set of vehicles is divided into clusters, in each one a cluster head (CH) is selected. This node accumulates packets and transmits them, according to the protocols used, to another mobile CH directly, or through fixed nodes. CH can relay messages to the ordinary nodes of its cluster using broadcast with a reduced transmitter power. A separate radio channel can be used for this one as well.

Necessary and Sufficient Conditions for Weak Separability Problem for Homogeneous Utility Functions

Aleksandr Shananin[1], **Sergey Tarasov**[2]

[1] *Moscow Institute Physics and Technology, Russia;* alexshan@yandex.ru
[2] *Moscow Institute Physics and Technology, Russia;*
serge99meister@gmail.com

Keywords: utility function, economic indices, weak separability property

Under the assumption that the utility function is positively homogeneous (PH in the sequel), we obtain necessary and sufficient conditions for weak separability problem.

Polyhedral Complementarity Algorithms for Exchange Model with Spending Constraints

Vadim Shmyrev[1]

[1] *Novosibirsk State University, Russia;* shmyrev.vadim@mail.ru

Keywords: exchange model, economic equilibrium, polyhedral complementarity, spending constraints, algorithm

A new development of polyhedral complementarity investigation is presented. This consideration extends the author's original approach to the equilibrium problem in a linear exchange model and its variations. The conceptual base of this approach is the scheme of polyhedral complementarity. It has no analogs and made it possible to obtain the finite algorithms for some variations of the exchange model. Especially simple algorithms arise for linear exchange model with fixed budgets (Fisher's model). This is due to monotonicity property inherent in the models and potentiality of arising mappings. It is natural to study applicability of the approach for more general models. Here the model with financial limits on purchases (spending constraints) is considered. Such a model can be used for studying of the piecewise linear version of the exchange model. A new algorithm for the model with the spending constraints is proposed.

Maximization of the Accumulated Extraction in a Gas Fields Model

Alexander Skiba[1]

[1] *Federal Research Center "Information and Control", Russian Academy of Sciences, Russia;* a.k.skiba@mail.ru

Keywords: optimal control, maximum principle, K. Arrow's proposition, mixed constraint, maximization of the accumulated extraction.

A continuous dynamic long-term model of the gas fields group is considered. Two problems are set and solved: the problem of maximizing accumulated production for a gas fields group over a fixed period and the problem of maximizing the length of the general "shelf" for fields group.

The problems proposed for the study belong to the class of optimal control problems with mixed constraints. The basic mathematical apparatus is Pontryagin's maximum principle in Arrow's form, in which Lagrange's multipliers are applied. The obtained results are analyzed.

On Existence of Optimal Non-Destructive Controls for Ecosystem Exploitation Problem Applied to a Generalization of Leslie Model

Alexander Smirnov[1]

[1] *Krasovskii Institute of Mathematics and Mechanics, Ural Branch of the Russian Academy of Sciences, Russia;* smale8@mail.ru

Keywords: nonlinear Leslie model, non-destructive exploitation of ecosystem, concave programming

Previously, we proposed some general formalization for the problem of sustainable use of renewable resources. The conditions for the stable existence of an exploited system, originally formulated in terms of asymptotic properties of some iterative process, were reduced to the existence of admissible controls for some mathematical programming problem. Here we examine some properties of admissible and optimal controls for this mathematical programming problem applied to the proposed by us nonlinear generalization of so-called Leslie's model of an ecosystem. Assuming concavity of all the nonlinear functions of this model, we show the existence of optimal controls that preserve all the structural units of the operated system. Moreover, the set of such controls, despite the nonlinearity of constraints, is a part of some hyperplane. In doing so, we use the introduced earlier by authors generalization of the classical concept of irreducibility for nonlinear maps.

Violation of Object Functional Unimodality and Evolutionary Algorithms for Optimal Control Problem Solution

Elena Sofronova[1], **Askhat Diveev**[2], **Anton Dotsenko**[3]

[1] *Federal Research Center "Control Science and Control" of Russian Academy of Sciences, Russia;* sofronova_ea@mail.ru

[2] *Federal Research Centre "Computer Science and Control" of Russian Academy of Sciences, RUDN University, Russia;* aidiveev@mail.ru

[3] *RUDN University, Russia;* anton.dozenko@gmail.com

Keywords: optimal control, unimodality of functional, evolutionary algorithms, phase constraints, robotics

Some common properties of violation of object function unimodality in optimal control problems is considered. Phase constraints and control object models for special symmetric systems are considered. It is shown that in a control problem by group of the objects, described by the symmetric system of equations, for certain initial and terminal conditions the functional is not unimodal. It is claimed that for optimal control problems with nonunimodal functionals it is efficient to use evolutionary algorithms. The theorem is proved that with particular conditions the convergence speed of evolutionary algorithms is higher than that of random search algorithm. An example of optimal control problem for a group of symmetric objects with phase constraints by evolutionary and gradient algorithms is presented.

Parameter Identification of Traffic Flows Control Model by Evolutionary Algorithms

Elena Sofronova[1], **Askhat Diveev**[2], **Anton Dotsenko**[3]

[1] *Federal Research Center "Control Science and Control" of Russian Academy of Sciences, Russia;* sofronova_ea@mail.ru

[2] *Federal Research Centre "Computer Science and Control" of Russian Academy of Sciences, RUDN University, Russia;* aidiveev@mail.ru

[3] *RUDN University, Russia;* anton.dozenko@gmail.com

Keywords: traffic flows control, identification, control synthesis, evolutionary algorithms

The work is aimed at development and research of mathematical model and algorithms for traffic flows control in urban road networks. The control of traffic flows is carried out by changing the durations of the working phases of traffic lights at intersections. To identify some parameters of the model evolutionary algorithms are proposed to be used as alternative algorithms for NP optimization problems.

Applications of Feedback Minimum Principle for Some Optimization Problems in Taxation

Stepan Sorokin[1], **Polina Sorokina**[2]

[1] *Matrosov Institute for System Dynamics and Control Theory, Russia;* sorsp@mail.ru

[2] *Baikal State University, Russia;* ermolaeva_polina@mail.ru

Keywords: optimal control, optimality condition, feedback maximum principle, losed loop controls, taxation

The major portion of available publications, devoted to the mathematical modeling of taxation, rely on the apparatus of mathematical statistics and econometrics. At the same time, dynamic models of such processes are studied rather poorly, not to say about associated optimal control problems. The talk is devoted to analysis of certain optimal control problems arising in the field of taxation. Our study follows a relatively novel approach, called the Feedback Minimum Principle (FMP), which was recently developed for some classes of nonconvex optimal control problems in continuous, discrete and impulsive dynamical systems. FMP is shown to improve the classical Pontryagin Maximum Principle and perform certain advantageous algorithmic features due to the usage of special auxiliary feedback controls, which serve one to design "counter" (open loop) controls with the property of potential improvement.

Software Implementation of Algorithms for Global Minimum Search Based on Nonlocal Methods for One-Dimensional Optimization

Pavel Sorokovikov[1]

[1] *Matrosov Institute for System Dynamics and Control Theory of SB RAS, Russia;* pavel2301s@gmail.com

Keywords: global optimization, global minimum, nonlocal one-dimensional search, algorithms library, software implementation

The paper presents a software implementation of algorithms for global minimum search based on nonlocal methods for one-dimensional optimization. Algorithms were implemented in the form of a C language library performed in a single software standard. The library includes the following algorithms: coordinate search, tunnel, Rosenbrock, partan, Powell, curvilinear search, spherical search. Modifications of the following one-dimensional algorithms have been developed and implemented: Yu.G. Evtushenko's, R. Brent's (with automatic evaluation of the Lipschitz constant), S.A. Piyavsky's, R.G. Strongin's, A. Zhiglyavsky's and A. Zilinskas's P-algorithms, A.Yu. Gornov's based on spline approximation, "parabolas", "compressive search", combined algorithm based on "parabolas" and R.G. Strongin's methods.

Multivariate computational experiments were performed with the use of the generated collection of test problems, which made it possible to identify the most competitive variants of algorithms.

Estimation of Multiproduct Models in Economics on the Example of Production Sector of Russian Economy

Ivan Stankevich[1], **Alexei Ujegov**[2], **Sergey Vasilyev**[3]

[1] *National Research University Higher School of Economics; The Lebedev Physical Institute of the RAS, Russia;* vpvstankevich@yandex.ru

[2] *National Research University Higher School of Economics, Russia;* ujegov@gmail.com

[3] *Federal Research Center "Computer Science and Control" of the RAS; The Lebedev Physical Institute of the RAS, Russia;* indianjoe92@gmail.com

Keywords: macroeconomic modeling, nonlinear models, gross domestic product (GDP), mathematical programming

The model of the real sector of Russian economy is presented. It allows for the separate description of GDP and its components by expenditure both in constant and in current prices. Unlike standard macroeconomic models, the model proposed considers a set of Trader agents in addition to Producer agent. Traders are based on a set of CES-functions and allow to decompose the statistics available into a set of unobserved components. The Producer is based on a specific production function that performs well for Russian data and works with financial variables, such as credits and bank accounts. In contrary to the standard approach, the model is not linearized to get estimates of model parameters but is estimated directly using a set of nonlinear equations. The optimization is performed numerically and allows to get both series of unobserved model products and their prices and model parameters. The stability of solution found is checked on simulated data.

Impulsive Relaxation of Continuity Equations and Modeling of Colliding Ensembles

Maxim Staritsyn[1], **Nikolay Pogodaev**[2]

[1] *Matrosov Institute for System Dynamics and Control Theory SB RAS, Russia;* starmaxmath@gmail.com

[2] *Matrosov Institute for System Dynamics and Control Theory, SB RAS, Russia;* nickpogo@gmail.com

Keywords: ensemble control, continuity equation, impulsive control, trajectory relaxation

The paper promotes a relatively novel class of multi-agent control systems named "impulsive" continuity equations. Systems of this sort, describing the dynamics of probabilistically distributed "crowds" of homotypic individuals, are intensively studied in the case, when the driving vector field is bounded and sufficiently regular. We, instead, consider the case when the vector field is unbounded, namely, it is affine in some controls, which are only integrally constrained. This means that the aforementioned crowd can be influenced by "shock" impacts, i.e., actions of small duration but very high intensity. For such continuity equations, we design an impulsive relaxation by closing the set of solutions (admissible arcs in the space of measures) in a suitable coarse topology. The main result presents a constructive form of the relaxed system. A connection of the obtained results to problems of contact dynamics is also discussed along with promising open issues.

Subgradient Method with Polyak's Step in Transformed Space

Petro Stetsyuk[1], **Viktor Stovba**[2], **Zhanna Chernousova**[3]

[1] *V.M. Glushkov Institute of Cybernetics of NAS of Ukraine, Ukraine;* stetsyukp@gmail.com

[2] *V.M. Glushkov Institute of Cybernetics of NAS of Ukraine, Ukraine;* vik.stovba@gmail.com

[3] *National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine;* chernjant@ukr.net

Keywords: Subgradient method, Polyak's step, Space transformation

We consider two subgradient methods (methods A and B) for finding the minimum point of a convex function for the known optimal value of the function. Method A is a subgradient method, which uses the Polyak's step in the original space of variables. Method B is a subgradient method in transformed space of variables, which uses Polyak's step in the transformed space. For both methods, a proof of the convergence of finding the minimum point with a given accuracy by the value of the function was performed. Examples of ravine convex (smooth and non-smooth) functions are given, for which convergence of method A is slow. It is shown that, with a suitable choice of the space transformation matrix, method B can be significantly accelerated in comparison with method A for ravine convex functions.

Global Optimality Conditions and Numerical Methods for Nonconvex Optimization Problems with D.C. Constraints

Alexander Strekalovskiy[1]

[1] *Matrosov Institute for System Dynamics and Control Theory of Siberian Branch of Russian Academy of Sciences, Russia;* strekal@icc.ru

Keywords: d.c. functions, equality and inequality constraints, exact penalty, linearized problem, global optimality conditions, KKT point, local search

The paper addresses the nonconvex nonsmooth optimization problem with the cost function and equality and inequality constraints given by d.c. functions. The original problem is reduced to a problem without constraints with the help of the exact penalization theory. After that, the penalized problem is represented as a d.c. minimization problem without constraints, for which the new mathematical tools under the form of global optimality conditions (GOCs) are developed. The GOCs reduce the nonconvex problem in question to a family of convex (linearized with respect to the basic nonconvexities) problems. It is worth noticing that the linearization was applied to the function which accumulates all the nonconvexities of the original problem. The GOCs are connected with the classical optimization theory and possess the so-called constructive property which allows one to escape local pitfalls provided, for instance, by the classical and the special optimization methods.

Forecasting Electrical Energy Consumption for Malfunction Detection in Complex Technical Systems

Anna Tatarczak[1], **Łukasz Wiechetek**[2], **Adam Kiersztyn**[3], **Marek Medrek**[4], **Jarosław Banaś**[5]

[1] *Maria Curie-Skłodowska-University, Poland;* anna.tatarczak@poczta.umcs.lublin.pl

[2] *Maria Curie-Skłodowska-University, Poland;* lukasz.wiechetek@umcs.pl

[3] *The John Paul II Catholic University of Lublin, Poland;* kierat@kul.lublin.pl

[4] *Maria Curie-Skłodowska University, Poland;* marek.medrek@umcs.pl

[5] *Maria Curie-Skłodowska-University, Poland;* jaroslaw.banas@umcs.pl

Keywords: data mining, anomaly detection, machine learning, Particle Swarm Optimization method, short-term trend

Issues related to the monitoring and detection of unexpected or hidden malfunctions in complex technical systems have become ever more important as the complexity of technical installations is growing. In the proposed solution, we use information concerning electricity consumption provided by smart energy metering technologies for monitoring and anomaly detection purposes.

We use the installations of a telco operator network as our data source, the data was produced by several hundred sources of various types, each created from many standardized components such as battery, transmitter, etc. We build an individual energy consumption model of each facility, which reflects daily cycles, weekly and seasonal fluctuations. For our simulations we use the Particle Swarm Optimization method, which allows us to parametrize the model and estimate the expected energy consumption rate. The results show convergence with measurement data and allow for real-time malfunction detection.

Ranking Allocation Scheme for Cost Sharing in Logistics

Anna Tatarczak[1], **Jarosław Banaś**[2], **Lech Kruś**[3]

[1] *Maria Curie-Skłodowska-University, Poland;*
anna.tatarczak@poczta.umcs.lublin.pl
[2] *Maria Curie-Skłodowska University, Poland;* jaroslaw.banas@umcs.pl
[3] *Systems Research Institute, Polish Academy of Sciences, Poland;*
Lech.Krus@ibspan.waw.pl

Keywords: logistics, horizontal cooperation, joint route planning, game theory, multi-criteria decision-making

By establishing collaborative relationships at the same level in the supply chain, companies can reduce logistics costs. This paper investigates the synergies between participants in logistics horizontal supply chain collaboration. In particular, carriers exploit synergies by using joint delivery mechanisms among themselves in order to reduce empty lanes and thus increase transportation savings. A key question is how the costs should be fairly distributed among the collaborative partners in order to ensure significant cooperation. Although there are studies on cost sharing using the game theory approach and other decision making techniques separately, according to the authors' knowledge there is no work that integrates these aspects in a common framework. This paper proposes an integrated method to solve such problems using the cooperating game theory with a view on spreading the cost among freight carriers. The effectiveness of the method is illustrated on a real-case example.

Simulations of Optimizing Strategies for Forming of Mutual Insurance Companies Fund

Nikolay Tikhomirov[1], **Tatiana Tikhomirova**[2], **Eldar Hamitov**[3]

[1] *Plekhanov Russian University of Economics, Russia;* tikhomirov.np@rea.ru

[2] *Plekhanov Russian University of Economics, Russia;* t_tikhomirova@mail.ru

[3] *Plekhanov Russian University of Economics, Russia;* hamitov.e.m@gmail.com

Keywords: mutual insurance, financial flows, stability of insurance companies, optimization, simulations

Mutual insurance companies are subject to high risks of ruin due to lack of funds. Thus, the problem of optimizing strategies for forming the company's fund are being actualized, ensuring an increase in its financial stability under assumed random insurance payments flow by rationalizing the size of initial and current contributions of its participants, the volume and time parameters of asset securitization, loans taken, insurance risk taxes taking into account the possibility of obtaining subsidies, reinsurance of risks and some other forms of the state support. The criterion in such task is the minimization of probabilities of the company's ruin. As restrictions costs of policyholders and the state can be considered but those determined by legislation. Because of the random nature of many indicators and the complex relations among them, it is rather difficult to obtain a solution to such optimization problems by analytical methods. For these purposes simulations are preferred.

Mirror Descent and Constrained Online Optimization Problems

Alexander Titov[1], **Alexander Gasnikov**[2], **Fedor Stonyakin**[3], **Mohammad Alkousa**[4]

[1] *Moscow Institute of Physics and Technology, Russia;* a.a.titov@phystech.edu

[2] *Moscow Institute of Physics and Technology, Russia;* gasnikov@yandex.ru

[3] *V. I. Vernadsky Crimean Federal University, Russia;* fedyor@mail.ru

[4] *Moscow Institute of Physics and Technology, Russia;* mohammad.math84@gmail.com

Keywords: online optimization, non-smooth constrained optimization, mirror descent

We consider the following problem. Assume, that N convex Lipschitz-continuous non-smooth functionals are given on a closed set of n-dimensional vector space. The problem is to minimize the arithmetic mean of functionals with a non-positive, convex Lipschitz-continuous non-smooth constraint g. In addition, it is allowed to calculate the (sub)gradient of each functional only once. Using some recently proposed adaptive methods of Mirror Descent the method is suggested to solve the mentioned constrained online optimization problem with optimal estimate of accuracy. For the corresponding non-Euclidean prox-structure the case of a set of n-dimensional vectors lying on the standard n-simplex is considered.

Mirror Descent and Constrained Optimization Problems with Quasiconvex Objective Functionals

Alexander Titov[1], **Fedor Stonyakin**[2], **Mohammad Alkousa**[3], **Alexander Gasnikov**[4]

[1] *Moscow Institute of Physics and Technologies, Russia;* a.a.titov@phystech.edu

[2] *V. I. Vernadsky Crimean Federal University, Russia;* fedyor@mail.ru

[3] *Moscow Institute of Physics and Technologies, Russia;* mohammad.alkousa@phystech.edu

[4] *Moscow Institute of Physics and Technologies, Russia;* gasnikov@yandex.ru

Keywords: Mirror Dscent, Quasiconvex Functional, Non-smooth Functional, Constrained problem, Optimal method

We consider the problem of minimizing of the quasiconvex Lipschitz-continuous non-smooth functional f with a non-positive, convex non-smooth Lipschitz-continuous constraint g. Adaptive and non-adaptive Mirror Descent methods are proposed. Depending on the value of the Lipschitz constant Mg of the constraint g it is possible to use one of the methods to get some advantages. For example, if Lipschiz constant $M_g < 1$ the non-adaptive method can work faster. Otherwise ($M_g > 1$) the non-adaptive method can guarantee better accuracy of the solution. Optimality for both methods is proved. Some cases of non-standard growth for smooth quasiconvex objective functionals are considered.

The research by Alexander Titov was supported by Russian Foundation for Basic Research according to the research project 18-31-00219. The research by Alexander Gasnikov and Fedor Stonyakin was supported by Russian Foundation for Basic Research according to the research project 18-29-03071.

Variation Method for Analyzing the Optimality of Stationary Points of a Polynomial and the Algorithm for Exact Geometric Search for Complex Roots

Sergey Trofimov[1]

[1] *Ural Federal University, Russia;* tsp61@mail.ru

Keywords: optimization, stationary point, local extremum, complex number, polynomial, complex roots, algorithm, exact geometric search

Method for analyzing the optimality of stationary points of polynomials is considered. We vary polynomial by a linear function with a small coefficient. Local extremum remains the only stationary point in its sufficiently small neighborhood. In the case of a false extremum, variation leads either to appearance of two stationary points, or to their disappearance from this neighborhood.

We introduce the concept of a complex stationary point of a polynomial as a complex root of its derivative. We show that the real stationary point is the intersection of several trajectories of complex stationary points of the perturbed polynomial. Analysis of these trajectories makes it possible to establish the optimality of the stationary point.

We propose an exact geometric algorithm for constructing complex roots of a polynomial with the order less 10. The algorithm allows one to represent real and complex roots of a polynomial on the same real plane.

Application of Infinitesimal One-Dimensional Analysis to the Study of Optimization Problems

Sergey Trofimov[1], **Alexey Ivanov**[2]

[1] *Ural Federal University, Russia;* tsp61@mail.ru
[2] *Ural Federal University, Russia;* av.ivanov.2014@yandex.ru

Keywords: infinitesimal function, logarithm of sum, generalized Taylor series, nondifferentiable optimization, duality gap, automated algorithm

Infinitesimal functions of one variable are approximated as the sum of monomials with unknown coefficients and fractional exponents. A special case of such series is the Puiseux series arising in the analysis of algebraic curves. An automated log-algorithm is proposed for simultaneous search for several monomials, based on the representation of the logarithm of the sum. A similar approach is used in geometric programming. The algorithm is used in the search for optimization problems with duality gap. The algorithm allows us to construct optimality criteria for nondifferentiable optimization problems. The algorithm is applied to the expansion of infinitesimal functions of several variables and generalizes the analogous Newton polygon method and the analysis of coercive functions. Numerical examples of the extraction of the first five fractional monomials from the infinitesimal function are given.

Optimization of Transmission Systems for Chain-Type Markets

Alexander Vasin[1], **Nikita Tsyganov**[2]

[1] *Lomonosov Moscow State University, Russia;* vasin@cs.msu.su
[2] *Lomonosov Moscow State University, Russia;* nikita--93@mail.ru

Keywords: mixed optimization problem, social welfare, transmission network

We consider a market for a homogeneous good with a chain-type transmission network. Every node corresponds to a local market with a perfect competition characterized by supply and demand functions. The initial transmission capacity, the cost of the capacity extension and the unit transmission cost are given for every transmission line. The cost of the capacity extension includes fixed and variable components. We examine the social welfare optimization problem for such a market. The welfare corresponds to the difference between the total consumption utility and the costs of production, transportation and extension of the transmission lines. Due to fixed costs of lines extension, the problem is in general NP-hard with respect to the number of the nodes. We generalize the concept of supermodularity of the welfare function on the set of extended lines and propose an algorithm for solution of the problem. Results of computer simulation confirm the statistical efficiency of the algorithm.

Comparison of Decisions Quality of Heuristic Methods Based on Modifying Operations in the Graph Shortest Path Problem

Eduard Vatutin[1], **Vladimir Panishchev**[2], **Svetlana Gvozdeva**[3], **Vitaly Titov**[4]

[1] *Southwest State University, Russia;* evatutin@rambler.ru
[2] *Southwest State University, Russia;* gskunk@yandex.ru
[3] *Southwest State University, Russia;* svetka-gvozdeva@yandex.ru
[4] *Southwest State University, Russia;* titov-kstu@rambler.ru

Keywords: heuristic methods, genetic algorithms, particle swarm optimization, random walks, simulated annealing, bee colony method, shortest path problem, discrete combinatorial optimization, BOINC

The article deals with the problem of analysis of effectiveness of the heuristic methods based on modifying the earlier found decisions in the test problem of getting the shortest path in graph. The article briefly describes the selected group of methods used to solve the problem. The methodology of experimental comparison for estimation the quality of solutions based on the performing of computational experiments with samples of graphs with pseudo-random structure using the BOINC platform is considered. It also shows description of obtained experimental results which allow to identify the areas of the preferable usage of selected subset of methods depending on the size of the problem and power of constraints. It is shown that the particle swarm optimization, random walks, simulated annealing and bee colony methods are ineffective in the selected problem and significantly inferior to the quality of solutions that are provided by ant colony optimization method and genetic algorithms.

Dimensionality Reduction for Time Series Decoding and Forecasting Problems

Mariia Vladimirova[1], **Roman Isachenko**[2], **Vadim Strijov**[3]

[1] *Moscow Institute of Physics and Technology, Russia;* mrvladimirova@gmail.com

[2] *Moscow Institute of Physics and Technology, Russia;* isa-ro@yandex.ru

[3] *A. A. Dorodnicyn Computing Centre of the Russian Academy of Sciences, Russia;* strijov@ccas.ru

Keywords: Time series decoding, Forecast, Partial least squares, Dimensionality reduction

The paper is devoted to the problem of decoding multiscaled time series and forecasting. The goal is to recover the dependence between input signal and target response. The proposed method allows to receive the predicted values not for next time stamp but for the whole range of values in forecast horizon. The prediction is multidimensional target vector instead of one timestamp point. We consider the linear model of partial least squares (PLS). The method finds the matrix of a joint description for the design matrix and the outcome matrix. The obtained latent space of the joint descriptions is low-dimensional. This leads to a simple, stable predictive model. We conducted computational experiments on the real data of energy consumption and electrocorticograms signals (ECoG). The experiments shows significant reduction of the dimensionality of the original spaces and models achieve good quality of prediction.

Multi-criteria decision-making system for detecting anomalies in the electrical energy consumption of telecommunication facilities

Łukasz Wiechetek[1], Jarosław Banaś[2], Adam Kiersztyn[3], Marek Medrek[4], Anna Tatarczak[5]

[1] *Maria Curie-Skłodowska-University, Poland;* lukasz.wiechetek@umcs.pl
[2] *Maria Curie-Skłodowska-University, Poland;* jaroslaw.banas@umcs.pl
[3] *The John Paul II Catholic University of Lublin, Poland;* kierat@kul.lublin.pl
[4] *Maria Curie-Skłodowska-University, Poland;* marek.medrek@umcs.pl
[5] *Maria Curie-Skłodowska-University, Poland;* anna.tatarczak@poczta.umcs.lublin.pl

Keywords: anomaly detection, energy consumption, Particle Swarm Optimization method, PSO, decision supporting system, telecommunications sector

The managers of the telecommunication infrastructure face the challenge of detecting and removing anomalies in the area of energy consumption. New technologies such as smart meters present new possibilities for the control and optimization of energy consumption.

The aim of the article is to present the framework of a tool for the detection of anomalies related to energy consumption. The developed multi-criteria system for anomaly detection (MSFAD) consists of three methods: time series prediction with Particle Swarm Optimization (PSO), categorization based on absolute energy consumption and segmentation with the use of relative changes in energy consumption. The framework was tested on the energy consumption logs received from a telecommunications company.

The analysis show that combining these methods may lead to improved feedback and increase the number of anomalies detected. That, in turn, would allow for a faster response, and increase the quality of the services provided.

Research and Optimization of Bragg Fiber-Optic Spectral Characteristics

Waldemar Wójcik[1], Piotr Kisała[2], Saltanat Amirgaliyeva[3], Aliya Kalizhanova[4], Gulzhan Kashaganova[5], Ainur Kozbakova[6]

[1] *Lublin Technical University, Poland;* waldemar.wojcik@pollub.pl

[2] *Lublin Technical University, Poland;* p.kisala@pollub.pl

[3] *Institute of Information and Computational Technologies of the CS MES RK, Kazakhstan;* saltanat_amirgal@mail.ru

[4] *Institute of Information and Computational Technologies of the CS MES RK, Kazakhstan;* kalizhanova_aliya@mail.ru

[5] *Institute of Information and Computational Technologies of the CS MES RK, Kazakhstan;* guljan_k70@mail.ru

[6] *Institute of Information and Computational Technologies of the CS MES RK, Kazakhstan;* ainur79@mail.ru

Keywords: Bragg fiber gratings, mathematical model, measurement methods, optimal parameters, spectral characteristics

The article herein is devoted to computing and measuring the basic parameters of Bragg fiber gratings, as well to the grating quality operation, definition of optimal parameter of their features.

Bragg fiber gratings (FBG) are widely used in different areas of modern fiber optics. Every task makes particular demands to Bragg fiber gratings spectral characteristics being , being set at the stage of gratings manufacturing.

Producing and using Bragg fiber optic gratings is not possible without measuring their characteristics at every stage of the gratings manufacturing and the devices on their basis. Researches, having been done within recent 30 years, allow effectively applying the BFG to telecommunication branch for dispersion equalization as optical filters, as well as, erbium doped fiber amplifiers and CDMA systems. BFG properties also allow using them as sensors of temperature, motion, stress, pressure.

Research and Optimization of Bragg Fiber-Optic Parameters

W. Wójcik[1], A. Kalizhanova[2], G. Kashaganova[3], S. Amirgaliyeva[4], P. Kisała[5], A. Kozbakova[6]

[1] *Lublin Technical University, Poland;* waldemar.wojcik@pollub.pl
[2] *Institute of Information and Computational Technologies CS MES RK, Kazakhstan;* kalizhanova_aliya@mail.ru
[3] *University of Power Engineering and Telecommunications, Kazakhstan;* guljan_k70@mail.ru
[4] *Institute of Information and Computational Technologies CS MES RK, Kazakhstan;* saltanat_amirgal@mail.ru
[5] *Lublin Technical University, Poland;* p.kisala@pollub.pl
[6] *Institute of Information and Computational Technologies CS MES RK, Kazakhstan;* ainur79@mail.ru

Keywords: Bragg fiber gratings, mathematical model, measurement methods, optimal parameters, spectral characteristics

Fiber Bragg Gratings (BFG) are widely used in different areas of the state-ofthe -art fiber optics. Every task imposes specified requirements to the BFG spectral characteristics, which are scheduled at the gratings manufacturing stage.

Manufacturing and using the Bragg fiber-optic gratings is impossible without measuring their characteristics at every stage of manufacturing the gratings themselves and devices on their basis.

The article is dedicated to the techniques of computing and measuring the BFG's principal parameters; it is necessary to define optimal parameters of the characteristics for the grating quality operation.

Task Assignment Optimization in Photoanalysis Process: Comparative Analysis of Semi-Automated and Manual Task Management

Uladzislau Yanch[1], **Łukasz Wiechetek**[2]

[1] *QMK sp. z o.o., Poland;* yanchvlad@gmail.com

[2] *Faculty of Economics, Maria Curie-Skłodowska University, Poland;* lukasz.wiechetek@umcs.pl

Keywords: Task assignment, Task management, Timetabling Problem, Personnel scheduling, Process optimization, Process automation, Optimizing in Excel, Solver, Comparative analysis

In today's competitive environment, enterprises strive to maintain high efficiency and quality of their business processes. This can be achieved using IT tools that allow to optimize tasks assignment and course of processes. The purpose of this article is to present the PESBAT – automation and optimization tool for task assignment, implemented in the VBA with the use of Solver add-in available in the Microsoft Excel.

The article presents the process of manual task assignment performed by a photoanalysis manager, components and basic functions of PESBAT tool. The main part of the article is a comparative analysis of semi-automatic and manual task division. The analysis shows that the combination of Solver algorithms and process automation through the use of macros implemented in VBA leads to time savings (20% to 60%) for task sets of various sizes and allows for more balanced task assignment, which reduces the time of order completion and improves quality of offered services.

A Numerical Comparison of CUSUM-Type Tests for Piecewise-Specified EGARCH-Models

Artem Yazykov[1], **Dmitriy Borzykh**[2]

[1] *FRC Computer Science and Control of RAS, NRU Higher School of Economics, Russia;* ayazikov@hse.ru

[2] *NRU Higher School of Economics, Russia;* dborzykh@hse.ru

Keywords: EGARCH, structural breaks, volatility, CUSUM

We studied the power of and precision with which the three well-known CUSUM-type tests (Tiao, 1994; Lee, 2000; Kokoszka, 1999) detect structural breaks in EGARCH-models. Despite being developed for GARCH-models, these tests are sometimes used for EGARCH-models in application to real financial time series (see, for example, (Morales, 2014)). However, there is no evidence that these tests are applicable for this type of models. We add to the literature by showing that the quality characteristics of the tests strongly depend on the values of the data generating process parameters.

The Weber Problem with Rectangular Facilities on Lines in the Presence of Forbidden Gaps

Gennady Zabudsky[1], **Natalia Veremchuk**[2]

[1] *Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences, Russia;* zabudsky@ofim.oscsbras.ru

[2] *Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences, Russia;* n-veremchuk@rambler.ru

Keywords: location problem, connected rectangular facilities, parallel lines

This article is devoted to the location problem of facilities on parallel lines in the presence of forbidden gaps. The placed facilities and the forbidden gaps are the rectangles. The centers of the facilities are connected between themselves and with the centers of the gaps. The facilities are impossible to place in forbidden gaps. In addition, a set of rectilinear passages between the lines is provided. The placed facilities must not cross the passages. It is necessary to place the facilities on the lines so that the total cost of connections between the facilities and between facilities and gaps was minimized. It is known that for oneline variant the original continuous problem is reduced to a number of discrete subproblems. In this article the review of properties and the algorithms for solving the problem is provided. Results of computational experiments for the branch and bound method, the heuristic and for solving the problem using the integer programming model are reported.

Pseudo-Boolean Black-Box Optimization Methods in the Context of Divide-and-Conquer Approach to Solving Hard SAT Instances

Oleg Zaikin[1], **Stepan Kochemazov**[2]

[1] *Matrosov Institute for System Dynamics and Control Theory SB RAS, Russia;* zaikin.icc@gmail.com

[2] *Matrosov Institute for System Dynamics and Control Theory SB RAS, Russia;* veinamond@gmail.com

Keywords: black-box optimization, pseudo-Boolean optimization, SAT, divide-and-conquer, cryptanalysis, stream cipher

Solving hard instances of the Boolean satisfiability problem (SAT) in practice is an interestingly nontrivial area. In particular, the heuristic nature of state-of-the-art SAT solvers makes it impossible to know in advance how long it will take to solve any particular SAT instance. One way of coping with this disadvantage is the divide-and-conquer approach when an original SAT instance is decomposed into several simpler subproblems. However, the way it is decomposed plays a crucial role in the resulting effectiveness of solving. In the present study, we reduce the problem of "dividing" a hard SAT instance into many simpler subproblems to a pseudo-boolean black-box optimization problem and use several relevant implementations of corresponding methods to analyze hard SAT instances encoding the cryptanalysis of state-of-the-art stream ciphers analyzed during the recent e-STREAM competition.

The Computational Technique for Nonlinear Nonconvex Optimal Control Problems Based on Modification Gully Method

Tatiana Zarodnyuk[1], **Aleksander Gornov**[2], **Anton Anikin**[3]

[1] *Matrosov Institute for System Dynamics and Control Theory of SB RAS, Russia;* tzarodnyuk@gmail.com

[2] *Matrosov Institute for System Dynamics and Control Theory of SB RAS, Russia;* gornov.a.yu@gmail.com

[3] *Matrosov Institute for System Dynamics and Control Theory SB RAS, Russia;* anton.anikin@gmail.com

Keywords: Global optimization, Optimal control problem, Numerical methods

The paper describes a technology for numerical investigation of nonlinear nonconvex based on MSBH method at the globalizing stage and the modified Nesterov's gully method at the stage of local extremum search.

We present two applied problems solving by proposed technique.

Numerical Investigation of the Optimal Control Problem Describing the Basic Quantum Logical Operations

Tatiana Zarodnyuk[1], Aleksander Gornov[2], Aigul Zinovyeva[3], Alexei Nenashev[4]

[1] *Matrosov Institute for System Dynamics and Control Theory of SB RAS, Russia;* tzarodnyuk@gmail.com

[2] *Matrosov Institute for System Dynamics and Control Theory of SB RAS, Russia;* gornov.a.yu@gmail.com

[3] *Rzhanov Institute of Semiconductor Physics of SB RAS, Russia;* aigul@isp.nsc.ru

[4] *Rzhanov Institute of Semiconductor Physics of SB RAS, Russia;* nenashev@isp.nsc.ru

Keywords: optimal control problem, computational experiment, quantum dot

The paper presents the research of the optimal control problem for a system of two quantum dots aimed at constructing a device for implementation the basic quantum logical operations. The corresponding mathematical model is represented in the form of a bilinear controllable system of differential equations with a given structure of controls.

The series of computational experiments performed for the basic quantum logical operations are carried out, the accuracy of their implementation is estimated. The results of these experiments confirmed possibility of realizing quantum operations within the framework of the considerable model.

Restoring Evaporation in a Model of Vertical Water Transfer in Soil

Sergey Zasukhin[1]

[1] *Moscow Institute of Physics and Technology, Russia;* s.zasukhin@yandex.ru

Keywords: water transfer in soil, inverse modeling approach, evaporation, numerical optimization, central limit theorem

A model of vertical water transfer in soil is considered. Evaporation from soil surface is an important component of this model. As a rule, experimental measurement of evaporation is a difficult task. An alternative to experimental measurements of evaporation can be its determination by application of inverse modeling approach. A criterion of the proximity of selected evaporation to its true value is mean-square deviation of prescribed values of soil moisture at various points from simulated soil moisture values corresponding to selected evaporation. In the presented paper, the numerical solution of the discretized optimization problem is investigated. The cases of accurate and inaccurate data are considered. The results of the numerical experiments are analyzed.

Identification of van Genuchten Parameters

Elena Zasukhina[1], **Sergey Zasukhin**[2]

[1] *Dorodnicyn Computing Centre of RAS, Russia;* elenazet2017@yandex.ru
[2] *Moscow Institute of Physics and Technology, Russia;* s.zasukhin@yandex.ru

Keywords: optimal control, nonlinear parabolic equation, uneven coatings, fast automatic differentiation

The problem of van Genuchten parameters identification is solved applying inverse modeling approach. The model of vertical water transfer in soil is considered. The problem of parameters identification is formulated as an optimal control problem. Controlled process is governed by one-dimensional non-linear parabolic equation. Objective function is mean-square deviation of simulated values of volumetric water content from some prescribed values. As a result of discretization, continuous optimal control problem is reduced to non-linear programming problem. It is proposed to solve the obtained problem numerically by the uneven coatings method.

Primal-Dual Newton's Methods with Steepest Descent for Linear Programming

Vitaly Zhadan[1]

[1] *FRC "Computer Science and Control" of Russian Academy of Sciences, Russia;* zhadan@ccas.ru

Keywords: Linear programming, primal-dual method, Newton's method, steepest descent, finite convergence

The primal-dual method for solving linear programming problems is considered.

In order to determine the search directions the non-perturbed system of optimality conditions is solved by Newton's method. If this system is degenerate, then an auxiliary linear complementarity problem is solved for obtained unique directions. Starting points and all consequent points are feasible. The step-sizes are chosen from the steepest descent approach based on minimization of the dual gap.

The safety factor is not introduced, and trajectories are allowed to move along the boundaries of the feasible sets. The convergence of the method at finite number of iterations is proved.

A Practical Vehicle Routing Problem with Time Windows and Simultaneous Deliveries and Pickups

Yakov Zinder[1], Anthony Mackay[2], Yefei Zhang[3], Lucy MacMillan[4], Hanyu Gu[5]

[1] *University of Technology, Sydney, Australia;* yakov.zinder@uts.edu.au
[2] *University of Technology, Sydney, Australia;*
[3] *University of Technology, Sydney, Australia;*
[4] *ANC, Australia;* lucym@ancdelivers.com.au
[5] *University of Technology, Sydney, Australia;*

Keywords: vehicle routing, simultaneous deliveries and pickups, single depot

We consider a vehicle routing problem with a heterogeneous fleet of vehicles and a single depot that arises in the retail sector. Each customer requires either a delivery from the depot, or a pickup of certain goods, previously delivered to this customer, or both. At most one vehicle can be allocated to a customer. The allocated vehicle can visit the corresponding customer only once and during this single visit must provide the all required service. The depot's loading capacity is limited and the vehicles arrive at the depot according to a given roster. The objective function is the number of customers. A novel iterated local search optimization algorithm is presented and compared by means of computational experiments with the approach, based on integer linear programming. The computational experiments used real-world data and show that the presented algorithm can be used in the real-time mode.

Multicriteria Model of Educational Process

Anna Zykina[1], **Olga Kaneva**[2], **Victoria Munko**[3]

[1] *Omsk State Technical University, Russia;* avzykina@mail.ru
[2] *Omsk State Technical University, Russia;* okaneva@yandex.ru
[3] *Omsk State Technical University, Russia;* vkreydunova@mail.ru

Keywords: Multicriteria programming, semi-structured data, uncertain data

The basic educational program formation is one of the most important problems in the educational process planning, taking into account the restrictions and requirements set by the Federal standard and the University in accordance with the competence approach. In the paper approach that determines the profile of the principal educational program is proposed. It includes the set of competencies that focused on the labor market. The constructed model of curriculum formation in association with the obtained set of profile competencies is a multi-criteria optimization problem. Approaches to the problem solution are proposed. This can lead to problems that associated with the formalization and generalization of semi-structured data. It can be processed by using modern decision-making methods under conditions of uncertainty initial data.

The Descriptor Approach Algorithm for Obtaining a Formalized Representation of the Concepts in the Educational and Professional Sphere

Anna Zykina[1], **Olga Kaneva**[2], **Ivan Sharun**[3]

[1] *Omsk State Technical University, Russia;* avzykina@mail.ru
[2] *Omsk State Technical University, Russia;* okaneva@yandex.ru
[3] *Omsk State Technical University, Russia;* prikladnay@yandex.ru

Keywords: descriptor approach, data analysis, scale of measurement

In this paper we suggest a model of formalized representation, that can be used in the educational and professional sphere of concepts ("competency", "direction", etc.). The model is based on the descriptor approach, i.e. concepts are described through descriptors "to know", "to able", etc. The level of descriptors and their values is enhanced by the level of terms and their weights for each descriptor value. This make possible to designed algorithms for finding the distance between described objects. It allows us to set and solve optimization problems with metric algorithms for data analysis. Descriptor entities (entities) is the concepts that can be described through such a structure. The article describes the algorithm for creating entities and gives examples of its use.

Author index