QIPA

3 — 5
DEC 2018

Conference handbook and proceedings

Quasilinear Equations, Inverse Problems and Their Applications

3 DECEMBER

Monday

9:30 Welcome

PLENARY SESSION

Phystech.Bio, 107 / Chair: J. Boman

10:00 **S.I. Kabanikhin** (ICM&MG SB RAS, Russia), M. Shishlenin, N. Novikov
Big Data and Gelfand-Levitan-Krein equations

10:35 **M. Agranovsky** (Bar-Ilan University, Israel)
On integrable domains and surfaces

11:10 **R.G. Novikov** (Ecole Polytechnique, France)
Moutard type transformations for generalized analytic functions

11:45 **V. Michel** (IMJ, France)
About the two dimensional conductivity inverse problem

12:20 Coffee break & lunch

SECTION 1

INVERSE PROBLEMS AND TOMOGRAPHY

Phystech.Bio, 107 / Chair: A. Laptev

13:20 **C. Shi** (University of Goettingen, Germany), O. Scherzer (University of Vienna & Johann Radon Institute, Austria), P. Elbau (University of Vienna, Austria)
Singular values of the attenuated photoacoustic imaging operator

13:55 **A.S. Shurup** (Moscow State University, Faculty of Physics, Russia)
Three-dimensional ocean acoustic tomography based on two-dimensional multichannel Novikov-Santacesaria algorithm

14:30 **A.D. Agaltsov** (Max Planck Institute for Solar System Research, Germany)
Fixed-frequency identities for the Green function and uniqueness results for passive imaging

15:05 **F.O. Goncharov** (Ecole Polytechnique, France)
Some numerical aspects of iterative inversions of weighted Radon transforms in 3D

15:40 Coffee break

Chair: A.S. Shurup

16:00 **E.V. Fadeev**, K.V. Dmitriev, O.D. Rumyantseva (Moscow State University, Faculty of Physics, Russia)
Restore point discontinuities and the analysis of the scattering of the retarded and advanced waves

16:35 **A.S. Leonov** (National Nuclear Research University MEPhI, Russia), A.B. Bakushinsky (Institute for Systems Analysis, Russia)
Numerical solving three-dimensional coefficient inverse problem for the wave equation with integral data in a cylindrical domain

17:10 **V. Filatova,** A. Danilin (Immanuel Kant Baltic Federal University, Russia)
Breast ultrasound tomography problem (3D simulation)

SECTION 2

INVERSE PROBLEMS IN ECONOMIC, FINANCE AND MEDICINE

Main building, 119 / Chair: Zhang Shuhua

13:20 **M. Marchenko**, O. Krivorotko, E. Kondakova (ICM&MG SB RAS, Russia)
Numerical solving the inverse problems for stochastic differential equations arising in economy

13:55 **M. Shishlenin** (Institute of Computational Mathematics and Mathematical Geophysics SB RAS, Sobolev Institute of Mathematics SB RAS (Russia)
Coefficient inverse problems for parabolic equations

14:30 **O. Krivorotko** (Institute of Computational Mathematics and Mathematical Geophysics of SB RAS, Novosibirsk State University, Russia)
Identification of mathematical models for social, epidemiological and economic processes

15:05 **D. Yermolenko** (Institute of Computational Mathematics and Mathematical Geophysics of SB RAS, Russia)
Regularizarion of the inverse problem for the mathematical model HIV dynamics

15:40 Coffee break

Chair: A.A.Shananin

16:00 **N.I. Klemashev** (Moscow State University, Russia)
Nonparametric methods for analyzing statistics by means of neoclassical demand model

16:35 **N. Pavlova** (MIPT, Russia)
Application of theory of coincidence points to investigation of economic models

17:10 **E. Serebryannikova**, A. Leonidov (LPI, MIPT, Russia)
The model of endogenous growth of the capital-labour ratio

17:45 **N. Trusov**
(Lomonosov Moscow State University, Russia)
Application of mean field games approximation to economic processes modeling

4 DECEMBER

Tuesday

PLENARY SESSION
Phystech.Bio, 107 / R.G. Novikov

10:00 **I.A. Taimanov**
(Sobolev Institute of Mathematics, Russia)
Darboux-Moutard transformations and Poincare-Steklov operators

10:35 **M.I. Belishev** (PDMI of RAS, Russia), A. Vakulenko
On algebra associated with 3d harmonic quaternion fields

11:10 **J. Boman** (Stockholm University, Sweden)
Radon transforms supported in hypersurfaces and a conjecture by Arnold

11:45 **A. Laptev** (Imperial College London, UK)
On factorisation of a class of Schrödinger operators

12:20 Coffee break & lunch

SECTION 1
INVERSE PROBLEMS IN MATHEMATICAL PHYSICS
Main building, 119 / Chair: I.A. Taimanov

13:20 **A. Jollivet** (CNRS & University of Lille, France)
Estimates for the Steklov zeta function of a planar domain

13:55 **A.S. Demidov** (Moscow State University, Russia)
On the search algorithm for all essentially different solutions of the inverse problem for the Grad-Shafranov equation

14:30 **M.I. Ismailov** (Gebze Technical University, Turkey)
Inverse scattering transform method for a nonlinear integro-differential evolution equation with 2+1 dimensions

15:05 **V.S. Dryuma** (IMI, Moldova)
On integrating of nonlinear differential equations in the field theory problems

15:40 Coffee break

Chair: M.I. Belishev

16:00 **A. Fomochkina** (Gubkin University, IEPT RAS, Russia), B.G. Bukchin (IEPT RAS, Russia)
The estimate of the errors of earthquake parameters determination from surface wave amplitude spectra

16:35 **M.M. Malamud** (RUDN, Russia)
Uniqueness results for first order systems of ODE

17:10 **V. Mikhaylov**, A. Mikhaylov (PDMI of RAS, Russia)
Inverse dynamic problem for Stieltjes string

17:45 **A. Kostenko**
(University of Vienna, Austria), J. Eckhardt
On the absolutely continuous spectrum of generalized indefinite strings

SECTION 2
QUASILINEAR EQUATIONS AND COMPUTATIONS
Phystech.Bio, 107 / Chair: L. Beklaryan

13:20 **A. Lapin** (Kazan Federal University (Russia), S. Zhang (Tianjin University of Finance and Economics, China), S. Lapin (Washington State University, USA)
Numerical solution of a parabolic optimal control problem with a controlled coefficient of state equation

13:55 **V. Vedenyapin** (Keldysh Institute Appl.Math., Russia)
Entropy in the sense of Boltzmann and Poincare

14:30 **A.V. Podoroga**, I.V. Tikhonov
(Moscow State University, Russia)
The exact method of solving quasilinear differential equations in some special cases

15:05 **N.I. Khokhlov**, N. Yavitch, M. Malovichko
(MIPT, Russia)
Comparison of the finite-difference and integral realization of Helmholtz's solver

15:40 Coffee break

Chair: V. Vedenyapin

16:00 **L. Beklaryan** (CEMI RAS, MIPT, Russia)
A. Beklaryan (National Research University Higher School of Economics, CEMI RAS, Russia)
Systems with polynomial potential. Existence of bounded and periodic soliton solutions. Numerical realization of soliton solutions

16:35 **A. A. Kozhemyachenko**,
I.B. Petrov (MIPT, Russia)
Calculation of interaction between railway and train

SECTION 3
NUMERICAL METHODS
Applied Mathematics building, 910 / Chair: I.B.Petrov

13:20 **A.A. Skubachevskii** (MIPT, Russia)
Numerical modelling of electromagnetic waves. FDTD and PIC methods

13:55 **K.A. Beklemysheva** (MIPT, Russia)
Numerical modeling of delamination in fiber-metal laminates caused by low-velocity impact

14:30 **V. Golubev**, A. Favorskaya (MIPT, Russia)
Some aspects of elastic migration in heterogeneous media

15:05 **B. V. Galitskii**, A. Favorskaya (MIPT, Russia)
Grid-characteristic method with a minimized number of computational operations

15:40 Coffee break

16:00 **P. Stognii** (MIPT, Russia)
Numerical modelling of 2D gas pockets spread in the Arctic zone

16:35 **A. Kabanova** (MIPT, Russia), A. Kozhemyatchenko (MIPT, Russia)
Numerical modelling of the damaged wheel and rail interaction using grid-characteristic method

17:10 **A. Gordov**, N.I. Khokhlov (MIPT, Russia)
Research of the numerical anisotropy for the grid-characteristic method for dynamic waves

17:45 **V. Axenov**, A. Vasyukov, K. Beklemysheva (MIPT, Russia)
Numerical simulation of membrane deformation under the high-speed load

5 DECEMBER

Wednesday

PLENARY SESSION
Phystech.Bio, 107 / Chair: S.I. Kabanikhin

9:25 **M. Ruzhansky** (Ghent University)
Very weak solutions for wave equations

10:00 **M.V. Pavlov** (FIAN Russia)
Integrability of the Benney system

10:35 **A.V. Arutyunov** (RUDN), E.S. Zhukovskiy (Tambov State University, Russia)
Variational Principles in Nonlinear Analysis

11:10 **V.P. Palamodov** (Tel Aviv University, Israel)
Reconstruction of the refractive index from single-distance radiograph

11:45 **A.G. Yagola** (Moscow State University, Russia)
A posteriori error estimates for solutions of inverse ill-posed problems

12:20 Coffee break & lunch

SECTION 1
MATHEMATICAL MODELING AND COMPUTATIONS
Phystech.Bio, 107 / Chair: A. Lapin

13:20 **S. Zhang** (Tianjin University of Finance and Economics, China)
A new idea for forecasting based on data-driven PDE and ODE

13:55 **A.V. Favorskaya** (MIPT, Russia)
A novel approach to study wave phenomena in heterogeneous media

14:30 **M. Elaeva**, E. Blanter (HSE, Russia)
Solar meridional flow through the inverse problem in the Kuramoto model with three oscillators

15:05 **A. Voloshin,** L. Pankratov (MIPT, Russia)
An upscaled Kondaurov type non-equilibrium model of two-phase flow in fractured non-homogeneous media

15:40 Coffee break

Chair: A. Lapin

16:00 **N.K. Volosova** (Bauman MSTU, Russia), D.F. Pastukhov (PSU, Belarus), K.A.Volosov (MIIT, Russia)
The expansion of the area of application of methods of mathematical physics for steganography

16:35 **D. Makarenko** (MIPT, Russia)
Non-gradient methods for determining the minimum energy of complex molecules.

17:10 **A.A. Shananin** (MPT, Russia)
Model of network economic structures

SECTION 2
OPTIMIZATION IN INVERSE PROBLEMS
Main building, 119 / Chair: Yu.G. Evtushenko

13:20 **M.V. Balashov** B. Polyak, A. Tremba (ICS RAS, Russia)
The gradient projection algorithm for smooth functions and prox-regular sets

13:55 **A. Ivanova** (MIPT, Russia)
Gradient descent for economical problem with several sectors.

14:20 V.M. Elsukov (MIPT, Russia)
Accelerated adaptive random block-coordinate descent

14:45 A. Rogozin, A. Gasnikov (MIPT, Russia), V. Potashnikov (IEP, Russia)
Selection of Economic Development Determinants via SEM Models

15:10 D.O. Selikhanovych (MIPT, Russia)
Comparison of variations of the linear coupling method

15:40 Coffee break

Chair: Yu.G. Evtushenko

16:00 A. Titov, A. Ivanova, M. Alkousa, A. Gasnikov (MIPT, Russia), F. Stonyakin (CFU, Russia)
One method for convex optimization problems with non-smooth strongly convex constraint

16:25 A. Agafonov (MIPT, Russia)
General scheme for estimating the rate of convergence in the strongly convex case

16:50 D. Dvinskikh (Weierstrass Institute Berlin)
Computation of non-regularized Wasserstein barycenter using KL prox-structure

18:00 CONFERENCE CLOSING

QIPA Quasilinear Equations, Inverse Problems and Their Applications

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S. Kabanikhin

M. Shishlenin, N. Novikov

Big Data and Gelfand-Levitan-Krein equations

In this talk coefficient inverse problems for hyperbolic equations are considered and investigated. The inverse problem consists of finding unknown coefficients by using additional information, which is given by measurement of the wave field on the surface of the medium.

We use the approach of I.M. Gelfand, B.M. Levitan and M.G. Krein to reduce nonlinear inverse problems to a family of linear integral equations. The main advantage of such approach is that method doesn't involve multiple solution of the direct problem. We present numerical methods based on the fast inversion of the Toeplitz matrix and tensor decomposition approach. We analyse the number of operations and conmpare it with standart methods. The results of the numerical experiments are presented.

M. Agranovsky

On integrable domains and surfaces

Integrability (algebraic, rational, polynomial) of a domain or a smooth hypersurface in Euclidean space is determined by the type of its volume function, evaluating the volumes of the intersections with hyperplanes. Study of integrable domains and surfaces is motivated by a conjecture of Arnold (in turn, going back to Newton's lemma about ovals) on algebraically integrable domains. We will discuss recent results which show that essentially, in accordance with the conjecture, only quadrics possess integrability.

R.G. Novikov

Moutard type transformations for generalized analytic functions

The transformations of the Darboux-Moutard type go back to the publication [1].

Recently, we have constructed and studied Moutard type transformations for generalized analytic functions(that is for the Carleman system or Bers–Vekua system) and further for the conductivity equation.

This talk is based, in particular, on works [2],[3] and [4].

[1]. T.F. Moutard, J. Ecole Polytechnique 45, 1-11 (1878)
[2]. P.G. Grinevich, R.G. Novikov, J. Geometric Analysis 26, 2984-2995 (2016)
[3]. R.G. Novikov, I.A. Taimanov, Russian Math. Surveys 71, 970-972 (2016)
[4]. P.G. Grinevich, R.G. Novikov, arXiv: 1801.00295 [math-ph].

V. Michel

About the two dimensional conductivity inverse problem

Let γ be a smooth real curve which is known to be the boundary of an unknown open smooth bordered orientable real surface M equipped with an unknown conductivity tensor $\sigma : T^*M \to T^*M$. Let $C\sigma$ be the unique complex structure on M for which σ is isotropic and $s\sigma : M \to]0,+\infty[$ the isotropy coefficient of σ relatively to $C\sigma$. The problem we consider is to find an effective construction for $(M,C\sigma,s\sigma)$ with data gathered from the Dirichlet-Neumman operator of σ and σ restricted to $T^*\gamma M$. The method we propose is to get first an embedding of the Riemann surface $(M,C\sigma)$ onto a complex curve S of CP_3 by finding the shock wave functions which describe the intersections of S with a family of complex lines. These shock waves are computed by solving linear systems whose number of unknowns can be bounded from above by available boundary data. The process is achieved by computing the isotropy coefficient with a result of Henkin and Novikov.

C. Shi

O. Scherzer; P. Elbau

Singular values of the attenuated photoacoustic imaging operator

In this talk, we will introduce photoacoustic tomography taking into account acoustic attenuation. We first present a unified attenuation model and then analyze the existence and uniqueness for the solution of this attenuation model. Then we divide the known attenuation models into two classes, called strong and weak attenuation. We show that for strong attenuation, the singular values of the attenuated photoacoustic operator decay exponentially, and in the weak attenuation case the singular values of the attenuated photoacoustic operator decay polynomially.

A. Shurup

Three-dimensional ocean acoustic tomography based on two-dimensional multichannel Novikov-Santacesaria algorithm

Ocean acoustic tomography is the unique approach for studying properties of world oceans both on the global (thousands kilometers) and on the regional (tens and hundreds kilometers) scales. Since the acoustic waves of relatively small frequencies are the single type of waves, which can propagate in the seawaters at such distances, nowadays the acoustic tomography is the actual and perspective field of scientific researches. The main properties of the oceans, which are required to be monitoring globally, are temperature distributions (closely connected with the sound speed of acoustic waves) and ocean currents (i.e. the space distribution of the vector of flows). The temperature of the oceans are the critic parameter defining the conditions of living on our planet. Monitoring of circulations of warm and cold water mases are required for understanding and predicting the critical changes in the world climate such as global warming.

There are some known methods for the solution of acoustic tomography problems, which are used in practice. In these approaches, the linear approximation is generally applied with iteration procedures and regularizations. On the other hand, there are quite mathematically rigorous (at least, for a rather wide class of scatterers) functional-analytical methods [1–5] for solving the inverse problems; these methods were initially developed in quantum mechanics. Nowadays, detail investigations based on numerical modeling are required to understand applicability of these methods for acoustics inverse problems.

In this report, the possibilities and limitations of Novikov-Santacesaria algorithm [3] for the purposes of ocean acoustic tomography are discussed. This algorithm takes into account the multiple scattering processes and does not require either linearization of the model or iterations. Moreover, the joint reconstruction of both scalar (i.e. sound speed) and vector (i.e. ocean currents) characteristics of the medium is possible in the unified tomography scheme. In addition, this algorithm gives the solution for two-dimensional multi-channel inverse problems. The example of such problems is the nonadiabatic propagation of hydroacoustic modes in three-dimensional inhomogeneous moving ocean. Results of numerical reconstructions of 3D ocean inhomogeneities based on the 2D multi-channel Novikov-Santacesaria algorithm are presented, which show high resolution and acceptable for practical applications the interference resistance of this algorithm.

The work was supported by RFBR grants № 16-29-02097 ofi_m and № 16-02-00680.

[1]. Grinevich P.G., Novikov R.G. Analogues of multisoliton potentials for the two-dimensional Schrödinger equations and a nonlocal Riemann problem // Soviet Math. Dokl. 1986. V. 33. N 1. P. 9–12.
[2]. Novikov R.G. The inverse scattering problem on a fixed energy level for the two-dimensional Schrödinger operator // Journal of Functional Analysis. 1992. V. 103. N 2. P. 409–463.
[3]. Novikov R.G., Santacesaria M. Monochromatic reconstruction algorithms for two-dimensional multi-channel inverse problems // International Mathematics Research Notices. 2013. V. 2013. N 6. P. 1205–1229.
[4]. Agaltsov A.D., Novikov R.G. Riemann–Hilbert problem approach for two-dimensional flow inverse scattering // J. Math. Phys. 2014. V. 55. N 10. P. 103502-1–103502-25.
[5]. Agaltsov A.D. On the reconstruction of parameters of a moving fluid from the Dirichlet-to-Neumann map // Eurasian Journal of Mathematical and Computer Applications. 2016. V. 4. N 1. P. 4–11.

A. Agaltsov

Fixed-frequency identities for the Green function and uniqueness results for passive imaging

For many wave propagation problems with random sources it has been demonstrated that cross correlations of wave fields are proportional to the imaginary part of the Green function of the underlying wave equation. This leads to the inverse problem to recover coefficients of a wave equation from the imaginary part of the Green function on some measurement manifold. In this talk I will present, in particular, local uniqueness results for the Schroedinger equation with one frequency and for the acoustic wave equation with unknown density and sound speed and two frequencies. As the main tool of the analysis, I will present new algebraic identities between the real and the imaginary part of Green's function, which in contrast to the well-known Kramers–Kronig relations, involve only one frequency.

This talk is based on the joint work with T. Hohage and R.G. Novikov https://arxiv.org/abs/1804.03375 (to appear in SIAM Journal on Applied Mathematics).

F.O. Goncharov

Some numerical aspects of iterative inversions of weighted Radon transforms in 3D

We consider weighted Radon transforms R_W with bounded strictly positive weights W along two-dimensional planes in $\mathbb{R}^3$. In this talk, first we briefly recall the results of [1, 2], explaining in which way R_W arise in the framework of different tomographies and how such transforms could be iteratively inverted.

Second, we present and discuss numerical results for our iterative inversion algorithm developed in [2].

[1]. Goncharov, F.O., Novikov, R.G., An analog of {C}hang inversion formula for weighted {R}adon transforms in multidimensions. Eurasian Journal of Mathematical and Computer Applications, 4(2):23-32, 2016.

[2]. Goncharov, F.O., An iterative inversion of weighted Radon transforms along hyperplanes. Inverse Problems (http://iopscience.iop.org/article/10.1088/1361-6420/aa91a4), 2017.

E.V. Fadeev

K. Dmitriev, O.D. Rumyantseva

Restore point discontinuities and the analysis of the scattering of the retarded and advanced waves

The scattering of plane acoustic waves by point and quasi-point (small wave size cylinders) two-dimensional inhomogeneities was studied. The field scattered by a point sound speed inhomogeneity is of monopole type. Its amplitude is uniquely related to the phase [1]. Such a scatterer can be replaced by a homogeneous quasi-point cylinder of small wave size with identical scattered field. Two kinds of scatterers can be distinguished, corresponding to values of the speed of sound greater or less than the background value. The inverse scattering problem was solved using the Novikov algorithm for both of this scaterers' kinds [2,3]. The reconstruction of the second kind scatterers is much more affected by errors caused by strong backscattering (due to a wide spatial spectrum of secondary sources) [4,5]. This is because such inhomogeneities focus incident field. In this case, one can improve the quality of reconstruction by filtering a part of input data associated with the backscattering [6].

The analogy between the point and quasi-point inhomogeneities allows us to further analyze the characteristics of the scattering of acoustic waves by density inhomogeneities and by inhomogeneities with absorption. For the case of an absorbing inhomogeneity of finite sizes, one can analyze the behavior of the complex scattering coefficients of retarded and advanced waves and the relationship of these coefficients.

The study was supported by the Russian Science Foundation, project no. 14-22-00042.

[1]. Burov V.A., Morozov S.A. Relationship between the amplitude and phase of a signal scattered by a point-like acoustic inhomogeneity // Acoustical Physics. 2001. V.47. N 6. P.659–664.
[2]. Badalyan N.P., Burov V.A., Morozov S.A., Rumyantseva O.D. Scattering by acoustic boundary scatterers with small wave sizes and their reconstruction // Acoustical Physics 2009. V.55. N 1. P.1–7.
[3]. Agaltsov A.D., Novikov R.G. Simplest examples of inverse scattering on the plane at fixed energy // 2017. https://hal.archives-ouvertes.fr/hal-01570494
[4]. Burov V.A., Rumyantseva O.D. Solution of the two-dimensional acoustical inverse scattering problem on the basis of functional-analytical methods: II. Range of effective application // Acoustical Physics. 1993. V.39. N5. P.419–424.
[5]. Burov V.A., Vecherin S.N., Morozov S.A., Rumyantseva O.D. Modeling of the exact solution of the inverse scattering problem by functional methods // Acoustical Physics. 2010. V. 56. N 4. P. 541–559.
[6]. Burov V.A., Alekseenko N.V., Rumyantseva O.D. Multifrequency generalization of the Novikov algorithm for the two-dimensional inverse scattering problem // Acoustical Physics. 2009. V.55. N 6. P.843–856.

A. Leonov

A. Bakushinsky

Numerical solving three-dimensional coefficient inverse problem for the wave equation with integral data in a cylindrical domain

A three-dimensional coefficient inverse problem for the wave equation (with losses) in a cylindrical domain is under consideration. The data for its solution are special time integrals of the wave field measured in a cylindrical layer. We present and substantiate an economical algorithm for solving such a three-dimensional problem based on the fast Fourier transform. The algorithm allows to obtain a solution on grids of size 512×512×512 in a time of about 1.4 hours on a typical PC without parallelizing the calculations. The results of numerical experiments for solving the corresponding model inverse problems are presented as well.

V. Filatova

A. Danilin

Breast ultrasound tomography problem (3D simulation)

The work is devoted to the problem of determining small sound speed fluctuations in glandular tissue for specific 3D breast model [1, 2]. Our approach, proposed in [3, 4], is based on visualization of inclusions and unknown inner boundary between fat and glandular tissues and determination of sound speeds in inclusions using kinematic argument. The results of numerical modeling in 3D are presented.

This work is supported by the Russian Science Foundation under grant 16-11-10027.

[1]. Nebojsa Duric and Peter Littrup (January 17th 2018). Breast Ultrasound Tomography, Breast Imaging // Cherie M. Kuzmiak, IntechOpen, DOI: 10.5772/intechopen.69794. Available from: https://www.intechopen.com/books/breast-imaging/breast-ultrasound-tomography
[2]. Duric, N., Littrup, P., Poulo, L., Babkin, A., Pevzner, R., Holsapple, E., ... & Glide, C. (2007). Detection of breast cancer with ultrasound tomography: First results with the Computed Ultrasound Risk Evaluation (CURE) prototype// Medical physics, 34(2), 773-785.
[3]. Filatova V.M., Nosikova V.V., Pestov L.N. Application of Reverse Time Migration (RTM) procedure in ultrasound tomography, numerical modeling // Eurasian Journal of Mathematical and Computer Applications, Vol. 4(4) (2016), PP. 5-13.
[4]. V.M. Filatova, V.V. Nosikova, Determining sound speed in weak inclusions in the ultrasound tomography problem// Eurasian Journal of Mathematical and Computer Applications, Volume 6, Issue 1 (2018) PP. 11 – 20.

M. Marchenko

O. Krivorotko; E. Kondakova

Numerical solving the inverse problems for stochastic differential equations arising in economy

We provide new parallel Monte Carlo methods to solve some inverse problems for stochastic differential equations arising in economy.

M. Shishlenin

S. Kabanikhin

Coefficient inverse problems for parabolic equations: application to medicine and finance

We consider two coefficient inverse problems for parabolic equations.

The first inverse problem consists on the recovering the leading time-dependent coefficient by known nonlocal additional information. For the approximate solution of the nonlinear inverse problems we propose the gradient method of minimization of the cost functional.

The second problem is connected to the financial mathematics. The data is given inside the domain on some curve and it is required to recover coefficients of the parabolic equation.

The results of numerical calculations are presented.

O. Krivorotko

Identification of mathematical models for social, epidemiological and economic processes

The specifics of the dissemination of information in society, the development of socially significant diseases (tuberculosis, HIV / AIDS) and economic processes depend on the region. One of the most effective methods is the development and identification of mathematical models that describe the processes of information dissemination in social networks, infections in the population and economic processes. Such models are described by systems of differential equations, the coefficients of that characterize the distribution of information, population, disease development and economic processes in the country. To identify these coefficients and initial conditions, that are not to be able for measurements, using some additional information about social, epidemiological and economic processes it is necessary to solve inverse problems. The Tikhonov regularization, gradient methods, stochastic approach (genetic algorithm, simulated annealing, particle swarm optimization) and tensor train decomposition are used for solving ill-posed inverse problems in variational formulation. A prototype of the digital Earth globe will be created with the possibility to visualize social, epidemiological and economic processes in various countries and continents based on mathematical modeling dynamic plug-in.

D. Yermolenko

Regularizarion of the inverse problem for the mathematical model HIV dynamics

In this paper a problem of specifying individual parameters of immunity and disease for a mathematical model of HIV dynamics using additional measurements of the concentrations of the T-lymphocytes, the free virus and the immune effectors at fixed times is investigated numerically. The stability of the inverse problem solution is analyzed using the singular value decomposition for linearized matrix of the inverse problem. The state variable observations are different from each other by orders of magnitude, intuitively, it is critical that the estimation scheme take this into account. One way to do this is by appropriately weighting the states in a least squares cost criterion. The problem of the parameter specifying of the mathematical model (an inverse problem) is reduced to a problem of minimizing an objective function describing the deviation of the simulation results from the experimental data. A genetic algorithm for solving the least squares function minimization problem is implemented and investigated. The results of a numerical solution of the inverse problem are analyzed.

N.I. Klemashev

Nonparametric methods for analyzing statistics by means of neoclassical demand model

The talk consists of three parts. In the first part we provide some evidence in favor of requiring positive-homogeneity of rationalizing utility function in the classical Pareto demand model by means of three numerical experiments, comparing strong and homothetic axioms of revealed preference in terms of finding separable commodity groups and forecasting.

In the second part we consider two models with several representative consumers – neoclassical and temporal dictator models. We show that the problems of testing economic data for consistency with these models are NP-complete. From these results we claim that in order to effectively analyze economic data in terms of models with many representative consumers, one needs to provide some modelling assumptions to overcome NP-completeness issues.

In the third part we present two studies of economic data, where such approach allowed affective analysis. In the first study we analyzed budget statistics of United Kingdom and revealed formation of a class of richer households. In the second study we analyzed Chinese stock market crisis in the summer of 2015. We managed to interpret it as the result of professional speculators accurately predicting future change in main investors' preferences.

N. Pavlova

Application of theory of coincidence points to investigation of economic models

The talk is devoted to the existence of equilibrium price vector in a supply-demand model. In this model, the demand function is the solution to the problem of maximizing the utility function under budget constraints. The supply function is the solution to the problem of maximizing the profit with given transaction losses on the technology set. Sufficient conditions for the existence of the equilibrium price vector are considered. These condition follows from existence theorems for coincidence points of covering and covering and Lipschitz continuous mappings.

E. Serebryannikova

A. Leonidov

The model of endogenous growth of the capital-labour ratio

The research on the endogenous economic growth is one of the fields where the methods from theoretical physics can be applied. Namely, evolution of the firms distribution by efficiency levels can be described by the kinetic equations. Such a description is a formal interpretation of the Joseph Schumpeter's ideas about the possibility of the bidirectional growth of the firms efficiency: the processes of innovations and imitations. In the current study the efficiency of a firm is represented by the capital-labour ratio. The optimal control model is proposed. The key assumption of the model is in description of the evolution of the firms distribution by the capital-labour levels in the form of difference-differential analogue of the Burgers type equation.

N. Trusov

Application of Mean Field Games approximation to economic processes modeling

This work relies on the results of a model presented by Fatone, L., Mariani, F., Recchioni, M.C. and Zirilli, F. (2014) (A Trading Execution Model Based on Mean Field Games and Optimal Control) and is its extension. We present a trading execution model of professional trader and retail traders on financial market. The behavior of retail traders is described by a system of PDE's that, by some assumptions, can be reduced to ODE's system. The optimal strategy of professional trader is based on optimal control theory.

I. A. Taimanov

Darboux-Moutard transformations and Poincare-Steklov operators

Formulas relating Poincare-Steklov operators for Schroedinger equations related by Darboux-Moutard transformations are derived. They can be used for testing algorithms of reconstruction of the potential from measurements at the boundary.

M. I. Belishev

A. Vakulenko

On algebra associated with 3d harmonic quaternion fields

The talk is devoted to the real uniform Banach algebra generated by the harmonic quaternion fields supported on a 3d smooth compact Riemannian manifold with boundary. Possible connections of this algebra with the reconstruction problem, which is to recover the manifold via its elliptic boundary data, are discussed.

J. Boman

Radon transforms supported in hypersurfaces and a conjecture by Arnold

A famous lemma in Newton's Principia says that the area of a segment of a bounded convex domain in the plane cannot depend algebraically on the parameters of the line that defines the segment. Vassiliev extended Newton's lemma to bounded convex domains in arbitrary even dimensions. In odd dimensions the volume cut out from an ellipsoid by a hyperplane depends not only algebraically but polynomially on the position of the hyperplane. Arnold conjectured in 1987 that ellipsoids in odd dimensions are the only cases in which the volume function in question is algebraic. The special case when the volume function is assumed to be polynomial has been studied in several papers and was settled very recently. Motivated by a totally different problem I recently tried to construct a compactly supported distribution $f \neq 0$ whose Radon transform is supported in the set of tangent planes to the boundary surface ∂D of a bounded convex domain $D \subset \mathbb{R}^n$. However, I found that such distributions can exist only if ∂D is an ellipsoid. This result gives a new proof of the abovementioned special case of Arnold's conjecture.

A. Laptev

On factorisation of a class of Schrödinger operators

The aim of this talk is to present sharp inequalities for 3/2 moments of the negative eigenvalues of Schrödinger operators on half-line that have a "Hardy term" in addition to a potential function.

A. Jollivet

Estimates for the Steklov zeta function of a planar domain

We address the question of reconstructing a bounded (simply connected) planar domain Ω with a C^∞ boundary \paΩ from the spectrum of its Dirichlet-to-Neumann operator (Steklov spectrum).

We review estimates from below for the Steklov spectral zeta function ζΩ on the real intervals (−∞,−1) and (1,+∞). Then we also remind additional estimates of ζΩ at even negative integers and a consequent compactness property of isospectral families of planar domains.

We finally discuss extension of our methods in aim of obtaining estimates on the real segment (−1,1).

A.S. Demidov

On the search algorithm for all essentially different solutions of the inverse problem for the Grad-Shafranov equation

We have in mind the inverse problem of the equilibrium of plasma in a tokamak and the inverse problem of magneto-electro-encephalography.

A general algorithm for searching all "physically meaningful" essentially different solutions of the inverse problem is as follows. First, some family of necessary conditions for the solvability of the inverse problem (whose union gives a sufficient solvability condition) is derived. After this, a “physically expedient” compact subset of desired functions f is chosen in which, as one can say, a minimal ε-net is constructed. (Recall that a set A is referred to as an ε-net for a compact subset C of the space X if C ⊂(A + BεX), where BεX is a ball in X of radical ε. If the ε-net contains minimally many elements, then it is called a minimal ε-net.) Further, a sequential search of the elements of this ε-net is carried out with simultaneous screening of the elements which fail to satisfy at least one necessary condition (in the above family) for the solvability of the inverse problem. Finally, the remaining elements and only these elements form the desired set of “physically meaningful” approximate solutions of the inverse problem.

M. Ismailov

Inverse scattering transform method for a nonlinear integro-differential evolution equation with 2+1 dimensions

We introduce a nonlinear 2+1 dimensional system of evolution equations related to the first-order nonstrict hyperbolic system. On the basis of the analysis of Gelfand–Levitan–Marchenko type integral equations corresponding to the inverse scattering problem for the first-order nonstrict hyperbolic system on the whole plane, we obtain a class of exact solutions of a nonlinear integro-differential equation with 2+1 dimensions.

V.S. Dryuma

On integrating of nonlinear differential equations in the field theory problems

In this talk will be considered some examples of nonlinear differential equations having the applications in theory of gage fields and which can be integrated with the help of parametric representation of the functions and their derivatives. In particular will be constructed the examplles of exact solutions of the SYZ-equation, which are important to the theory of Calaby-Yau manifolds.

A. Fomochkina

B. Bukchin

The estimate of the errors of earthquake parameters determination from surface wave amplitude spectra

We consider instant point shear dislocation (double-couple). Such a seismic source is given by its depth, the focal mechanism determined by three angles (strike, dip, slip) and the seismic moment. We determine these parameters by a systematic exploration of their possible values and by minimization of the misfit between observed and calculated amplitude surface wave spectra. We estimate the errors of their determination using Jackknife technique.

M.M. Malamud

Uniqueness results for first order systems of ODE

The problem of unique determinantion of a normalaized system of ordinary differential equations on a finite interval by a part of its monodromy matrix will be discussed. Selfadjoint case will be discussed in detail.

V. Mikhaylov

A. Mikhaylov

Inverse dynamic problem for Stieltjes string

We consider the inverse dynamic problem for dynamical system associated with Stieltjes string (i.e. Krein string with point masses). We derive equations of inverse problem and answer the question on characterization of dynamic inverse data.

A. Kostenko
On the absolutely continuous spectrum of generalized indefinite strings

Our main result is the stability of the absolutely continuous spectra of two model examples of strings under rather wide classes of perturbations. In particular, this enables us to prove that the absolutely continuous spectrum of the isospectral problem associated with the conservative Camassa--Holm flow in the dispersive regime is essentially supported on the interval [1/4,∞) for the entire natural phase space.

A. Lapin
S. Zhang, S. Lapin
Numerical solution of a parabolic optimal control problem with a controlled coefficient of state equation

We construct and study finite difference approximations of optimal control problems arising in the mathematical modeling of certain management and financial problems. The numerical calculation results are presented for 1D and 2D problems. To approximate the state equations we use implicit (backward Euler) and fractional steps (operator splitting) methods. The solutions of the constructed mesh state equations are strictly positive and keep an analogue of the mass balance condition. We provide the existence results and first order optimality conditions for the corresponding mesh optimal control problems. We use several iterative methods to implement the constructed nonlinear optimization problems and compare their effectiveness.

V. Vedenyapin
Entropy in the sense of Boltzmann and Poincare

Entropy in the sense of Boltzmann and Poincare. Boltzmann in 1872[1] introduced equations of chemical kinetics and investigated for them growth of special function, which was named entropy or H-function with opposite sign. A discussion round this theorem with Loshmidt and Zermelo paradoxes brought Poincare to investigation of H-theorem for Lioville equation. In 1906 he published a paper [2] where founded, that although entropy conserves due to Lioville equation, its value of entropy for limit distribution function when time tends to infinity is greater than for initial. This paper was unrealizable and criticized for a long time, but was studied and generalized by V.V. Kozlov in 2001-2008 [3]. The H-theorem is proved for generalized equations of chemical kinetics, and important physical examples of such generalizations are considered: a discrete model of the quantum kinetic equations (the Uehling–Uhlenbeck equations) and a quantum Markov process (a quantum random walk). The time means are shown to coincide with the Boltzmann extremes for these equations and for the Liouville equation[4]. This give possibility to prove existence of analogues of action-angles variables in nonhamiltonian situation. For this purpose we use hydrodynamic substitution, which was invented for derivation of hydrodynamics from Vlasove-type equations [5-9].

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A. Podoroga

I. Tikhonov

The exact method of solving quasilinear differential equations in some special cases

We propose a numerical method for finding entropy solutions of a first-order quasilinear differential equation. It is possible to obtain an exact solution of the Cauchy problem under the following two restrictions. First, it is assumed that the flow function is piecewise linear, and second, it is required that the initial condition is a piecewise constant. We emphasize especially that nonconvex flow functions are also included in our method. The construction of solutions occurs through the motion of shock waves, taking into account the known conditions of Hugoniot and Oleinik. The method is implemented as a computer program. In the report we provide examples and illustrations.

N. Khokhlov

N. Yavitch, M. Malovichko

Comparison of the finite-difference and integral realization of Helmholtz's solvation solver

The method of integral equations makes it possible to reduce the size of the problem, in this implementation makes it computationally acceptable. In this case, the number of conditionality of the resulting matrix is much lower than in the finite-difference discretization. In the work, a study was conducted in which cases is computationally more efficient than the finite-difference method.

L. Beklaryan

A. Beklaryan

Systems with polynomial potential. Existence of bounded and periodic soliton solutions. Numerical realization of soliton solutions

For equations of mathematical physics, which are the Euler-Lagrange equation of the corresponding variational problems, an important class of solutions are soliton solutions. In a number of models, such solutions are well approximated by soliton solutions for finite-difference analogues of the initial equations, which, in place of a continuous environment, describe the interaction of clumps of a environment placed at the vertices of the lattice. Emerging systems belong to the class of infinite-dimensional dynamical systems. The most widely considered classes of such problems are infinite systems with Frenkel-Kontorova potentials (periodic and slowly growing potentials) and Fermi-Pasta-Ulam (potentials of exponential growth).

In the framework of the developed approach, the study of soliton solutions (solutions of the traveling wave type) is based on the existence (in case of the quasilinear right-hand side of the functional differential equation) of a one-to-one correspondence between soliton solutions for infinite-dimensional dynamical systems and solutions of induced functional differential equations of pointwise type (FDEPT). In fact, the described connection between solutions of the traveling wave type of the infinite-dimensional dynamical system and solutions of the induced FDEPT is a fragment of a more general scheme that goes beyond the scope of this talk. The bounded and periodic soliton solutions of an infinite-dimensional dynamical system form an important class of solutions both for quasilinear and polynomial potentials. The most important element of the developed formalism is the equivalence of the description of soliton solutions of an infinite-dimensional dynamical system to the description of solutions of an induced FDEPT.

Another class of problems is related to the study of soliton solutions for equations of mathematical physics without using finite-difference analogs. At the same time, the potentials can have lags in time. In this case, the induced equation for traveling waves also turns out to be a FDEPT.

For both classes of problems, the existence and uniqueness theorem for a solution of an induced FDEPT guarantees the existence and uniqueness of a soliton solution with given initial values for systems with quasilinear potential. Moreover, for systems with a quasilinear potential, one can formulate the conditions for the existence of a bounded and periodic solution. The formulated conditions, as well as the estimate of the radius of the ball in which the solution is contained, are given in terms of the characteristics of the right-hand side of the induced FDEPT: the Lipschitz constant, the deviation of the argument, and the characteristic of the traveling wave. It is very important that such conditions do not use information about the spectral properties of the linearized equation (equations in variations) that essentially simplifies their verification. A system with a polynomial potential can be redefined by changing the potential outside a given ball, so that the emerging potential turns out to be quasilinear. If a guaranteed periodic soliton solution for such an overdetermined system lies in the ball outside which the potential is redefined, then we obtain the conditions for the existence of a bounded and periodic soliton solution for the initial system with a polynomial potential. Another important task is the numerical realization of bounded and periodic soliton solutions for systems with a polynomial potential, which has been successfully solved.

A.A. Kozhemyachenko

I.B. Petrov

Calculation of interaction between railway and train

Investigation of wave phenomena is useful in applied problems related to improving rail safety. So the authors have already investigated the problem of pressure of a wagon or locomotive on railway tracks by grid-characteristic method. In this talk a more general formulation of the problem is considered, namely the pressure of the railroad train on the railway. The grid-characteristic method on structured grids is used. A complete system of equations is solved that describes the state of a continuous linearly elastic medium with explicit separation of contact boundaries in the heterogeneous structure of the railway tracks. Features of calculation of pressure of train on railway are presented. The results of computer simulation are given. The reported study was funded by RFBR and JSC Russian Railways according to the research project № 17-20-01096.

A. A. Skubachevskii

Numerical modelling of electromagnetic waves. FDTDand PIC methods

In this talk I will speak about FDTD and PIC methods, implemented in my program. The program was verified on plane waves and electrons. It is used for modelling of more complex electromagnetic fields in various medium. I will also mention some interesting facts, concerning plane waves and trajectory of particles, found during the verification.

K.A. Beklemysheva

Numerical modeling of delamination in fiber-metal laminates caused by low-velocity impact

The grid-characteristic method (GCM) used in this research showed good results in many areas that require modeling of the elastic wave pattern: seismic survey, ultrasound, failure of fragile materials. Barely visible impact damage that occurs in composites under a low-velocity impact can also be ex-plained in terms of interaction of elastic waves with the complex structure of a composite. One of the most dangerous damage types is delamination, because it reduces the longitudinal compression strength of the material. The GCM allows using various types of border and contact conditions, including elliptic contact destruction criterion. Several problem statements are considered to demonstrate capabilities of the method. A comparison with exper-imental data is performed, resulting in a qualitative agreement.

V. Golubev

A. Favorskaya

Some aspects of elastic migration in heterogeneous media

Nowadays different migration algorithms are intensively used in the oil and gas industry. Most of the commercial software are based on the acoustic approach which ignores the propagation of reflected shear waves. With the modern HPC systems it is possible to extend the general method to the elastic case. In this report different elastic approaches were tested and pros and cons of them were clearly shown. The way of further developments was determined.

The research was supported by the grant of the President of the Russian Federation No. MK-1831.2017.9.

B.V. Galitskii

A. Favorskaya

Grid-characteristic method with a minimized number of computational operations

Grid-characteristic method was first proposed by Prof A.S. Kholodov and Prof K.M. Magomedov. Later the method was widely developed by the scientific team leading by Prof I.B. Petrov. At present, this method is used to solve problems from various fields, i.e. seismic prospecting of hydrocarbons, ultrasonic non-destructive testing, including investigation of railroad tracks, composite materials, and human body, for solving applied problems in the interests of the railway and building industry. Regular computational grids are often used. The corresponding mathematical expressions that arise in the computational algorithms can be greatly simplified for the case of regular computational grids, thereby substantially reducing the number of computational operations and increasing the efficiency of the numerical method. The report deals with the corresponding mathematical expressions with a minimized number of operations received by the authors. Comparative estimates are given for minimizing the number of computational operations due to the use of these optimized mathematical expressions.

P. Stognii

Numerical modelling of 2D gas pockets spread in the Arctic zone

Gas layers often come out from soil outside into the atmosphere in the Arctic zone. It is very important to be able to take appropriate measures for minimizing the damage while these blowouts, and that's why modelling of geological gas containing layers is being held. This work represents the results of 2D modelling for gas spread towards the surface of water in the Arctic region.

The reported study was funded by RFBR according to the research project № 16-29-02018 ofi_m.

A. Kabanova

A. Kozhemyatchenko

Numerical modelling of the damaged wheel and rail interaction using grid-characteristic method

A calculation method for the impact of a damaged wheel with a flat spot on a rail is proposed. The approach makes possible to vary the wheelset damage rate, types of train cars, locomotives or rails, the space between sleepers, weather conditions, and characteristics of the enclosing geological environment. Combined calculations are used for the problem solving. The pressure of the moving wheelsets is calculated with the use of applied analytical expressions. The impact of wheels with flat spots on the rail is taken into account with the use of developed analytical expressions. A complete state equations system that corresponds for a continuous linear-elastic medium in a rail, sleepers, an embankment and a sedimentary cover with varying of elastic waves velocities, the materials density and the model geometry is developed. This equations system is solved in the time domain with the use of the grid-characteristic method.

A few versions of a train car with undamaged wheelset and of a train car with a wheelset with a flat spot are considered. Two train speeds are used. The calculated results of cracks formation modelling are in a good agreement with the transportation standards of train cars and locomotives with damaged wheelsets to repair stations. The approach can be used for criteria development for train cars and locomotives transportation in case of flat spots corresponding to various special conditions. The physical analysis of the damage processes in the railway track can be used with help of the thorough analysis of elastic wave processes in the rail occurring during the train movement and in a moment when a damaged wheel strikes the rail. The research can help in new strategies development for timely wheel defect detection, for declining railway track damages and for timely wheelset replacement. Not only the shock damaged calculation method is suggested but also an approach for taking into account the fatigue cracks.

The reported study was funded by RFBR and JSC Russian Railways according to the research project № 17-20-03057.

A. Gordov

N.I. Khokhlov

Research of the numerical anisotropy for the grid-characteristic method for dynamic vawes

In this talk would be presented results of the research of the numerical anisotropy for the grid-characteristic methods for dynamic waves for the different time splitting schemes.

V. Axenov

A. Vasyukov, K. Beklemysheva

Numerical simulation of membrane deformation under the high-speed load

The dynamic problem of the development of stresses and deformations in a thin membrane under a strike load is considered. High-speed interactions are considered, for which wave processes are essential, since the exposure time is comparable to the propagation time of acoustic waves in the membrane. The load is assumed asymmetric, distributed over time and space. Based on this formulation, a thin membrane model (2D object) in 3D space is used. For the numerical solution, an explicit calculation scheme is used. This task is the first step in solving the inverse problem of optimizing the structure of the membrane.

M. Ruzhansky

Very weak solutions for wave equations

In this talk we will discuss the recent notion of very weak solutions, aimed at proving the well-posedness and further properties of partial differential equations with singular (distributional) coefficients. We will discuss several physical models and show numerical experiments.

M.V. Pavlov

Integrability of the Benney System

We show that three-dimensional Benney system (two spatial and one temporal variables) can be reduces to a two-dimensional problem (one spatial and one temporal variables) determining a velocity profile.

A.V. Arutyunov

E.S. Zhukovskiy

Variational Principles in Nonlinear Analysis

Functions defined on metric spaces are studied. For these functions, a generalized Caristi-like condition is introduced. It is shown that this condition is sufficient for a bounded below lower semicontinuous function to attain its minimum. Generalizations of Ekeland and Bishop-Phelps variational principles are obtained and compared with their prototypes.

V.P. Palamodov

Reconstruction of the refractive index from single-distance radiograph

The lensless diffractive X-ray technic for micro-scale imaging of biological tissue yields improved contrast compared to purely absorption-based radiography but involves a phase retrieval problem since of physical limitation of detectors. A general method is proposed for one step reconstruction of ray integrals of complex refractive index of optically weak object from intensity distribution of the hologram.

A.G. Yagola

A posteriori error estimates for solutions of inverse ill-posed problems

In this talk I will consider different approaches for constructing error for solutions of ill-posed problems.

The work was supported by the Russian Foundation for Basic Research (grants no. 17-01-00159-a and 16-01-00450a).

S. Zhang

A new idea for forecasting based on data-driven PDE and ODE

Accurate reporting and forecasting of PM2.5 concentration are important for improving public health. In this paper, we propose a partial differential equation (PDE) model, specially, a linear diffusive equation, to describe the spatial-temporal characteristics of PM2.5 in order to make short-term prediction. We analyze the temporal and spatial patterns of a real dataset from China's National Environmental Monitoring and validate the PDE-based model in terms of predicting the PM2.5 concentration of the next day by the former days' history data. Our experiment results show that the PDE model is able to characterize and predict the process of PM2.5 transport. For example, for 300 continuous days of 2016, the average prediction accuracy of the PDE model over all city-regions is 93% or 83% based on different accuracy definitions. To our knowledge, this is the first attempt to use PDE-based model to study PM2.5 prediction in both temporal and spatial dimensions.

A.V. Favorskaya

A novel approach to study wave phenomena in heterogeneous media

A novel approach to analyze wave phenomena is proposed by studying the wave patterns (sets of wave field snapshots) calculated on the basis of full-wave simulation in the time domain on detailed calculation meshes and visualized in a special way, and by further obtaining analytical expressions or qualitative regularities in wave dynamics. Several results had been obtained using this technique so-called Wave Logica. The responses from transverse waves in the water layer are revealed and investigated. The corresponding analytical expressions are obtained. A method of geophysical research based on the response data was developed and patented. The waves which occur during a falling plane wave scattering on a vertical gas-filled fracture are revealed and investigated. The appropriate analytical expressions are obtained. The possibility of multiple waves using to obtain information about the underlying geological massif is given. The appropriate analytical expressions explaining the effect are obtained. A technique for using multiple waves is proposed to study the geometric parameters and elastic characteristics of materials, including using laser ultrasound. The dependence of the trajectory and the velocity of motion of the point of separation of the longitudinal head wave from the transverse wave from the frequency of the source of elastic waves is revealed and investigated. A difference between the frequency of the waves scattered on a fractured cluster and the frequency of the source is found.

M. Elaeva

E. Blanter

Solar meridional flow through the inverse problem in the Kuramoto model with three oscillators

We apply the Kuramoto model with three coupled oscillators to the modeling of the solar meridional flow. The model is assumed to be symmetrical and the frequency of the middle oscillator is assumed to be near zero. The angular velocity of the meridional flow at the solar surface and at the boundary of the convection zone are reconstructed. It is analytically demonstrated that the ratio between the velocity of the meridional flow near solar surface and in the boundary of the convection zone should be greater than two. This result agrees with helioseismological observations.

A. Voloshin

L. Pankratov

An upscaled Kondaurov type non-equilibrium model of two-phase flow in fractured non-homogeneous media

We derive an upscaled model of the incompressible two-phase flow in fractured porous media consisting of disjoint non-homogeneous porous blocks surrounded by highly permeable connected fissure system. The upscaling process consists of two steps. At the first step a Kondaurov type non-equilibrium flow model on the mesoscale level is derived. This model takes into account the capillary non-equilibrium effects of the flow in the blocks and fractures. Upscaling the mesoscale model, we obtain the desired macroscopic (homogenized) Kondaurov's type model. The upscaling process at the second step is justified by the numerical simulation.

N.K. Volosova

D.F. Pastuhov, K.A. Volosov

The expansion of the area of application of methods of mathematical physics for steganography

Considers areas with complex distributed sources. Suggested use iteration with linear systems, a Radon transform or the boundary value problem Dirichlet problem for the Poisson equation. In the last two cases are solved in the inverse problem. An efficient iterative formula for the case when the sources are distributed is difficult.

Keywords: Radon transform, iterative methods, the Poisson equatio

D. Makarenko

Non-gradient methods for determining the minimum energy of complex molecules

In order to conduct effective drug therapy, there is a need to create artificial biological molecules that meet the required properties. Ensuring the possibility of rational design of such molecules, as well as the prediction of their properties without conducting a real biological experiment, is one of the most important goals of modern computational biology.

To find the mutual position of all atoms in the molecule, corresponding to the state of a biological object in nature, consider optimizing the geometry of the object under study. It is known that in nature, the structure of a protein does not correspond to the global minimum of potential energy, which leads to the idea of finding a locally close geometry corresponding to a lower energy.

The optimized energy functional is constructed in accordance with the OPLS model. This problem is essentially nonconvex. The optimized functional is smooth, but the Lipschitz constant can be significant. But in this case, to minimize the functional use of gradient methods will be difficult. Thus, to solve this problem of unconditional optimization, it is worth considering a class of non-gradient methods. In this talk, we investigated the method of coordinate descent with adjustable step length.

A. A. Shananin
Model of network economic structures

The transportation mathematicalproblem is modified for the analysis of network economic structures. A variation principle in the form of a pair of mutualy dual convex programming problems is constructed and a competitive equilibrium in the transportation model is found from this principle. An approach to the analysis of imperfect competition, distribution of the intermediary's profit, and the role of communication constraints in a transportation metwork is proposed. Weconsider the inverse problems for the model of network economic structures.

M.V. Balashov
B. Polyak, A. Tremba
The gradient projection algorithm for smooth functions and prox-regular sets

We'll discuss some gradient projection algorithms for smooth functions and prox-regular sets. We don't propose convexity of considered sets and functions.

A. Ivanova
Gradient descent for economical problem with several sectors.

In this paper, we consider the economic problem for several sectors of the economy. To solve this problem, the proposed method of solving it for an optimization problem that satisfies the condition of gradient dominance. To solve obtaining problem we choosing a gradient descent with adaptive stepsize. Methods for choosing the initial approximation for gradient descent are studied. A condition on the choice of constants of equations to perform inter-branch balance is obtained. To confirm the theoretical result, numerical experiments were performed.

V.M. Elsukov
Accelerated adaptive random block-coordinate descent

The problem of convex optimization on the direct product of simplices arises in such problems as searching for equilibria in potential loading games with multiple populations and machine learning. In these problems, the dimensions reach large sizes and it is expensive to obtain prior information about a function such as the Lipschitz constant. These difficulties can be avoided by using the adaptive block-by-component version of the usual method.

In this paper we propose a generalization of the accelerated linear coupling method to a block-component version with a simplex constraint, where the Lipschitz constant is chosen in an adaptive way. According to the https://arxiv.org/pdf/1512.09103.pdf a non-uniform sample was used that selects each block and was obtained the evidence of assessments of the convergence rate.

A. Rogozin

V. Potashnikov, A. Gasnikov

Selection of Economic Development Determinants via SEM Models

In this work, we study how to find main determinants of economic development. Economic factors and development itself are represented by random variables and are related to each other through a system of linear equations.

More specifically, we consider simple SEM models with 3 exogenous, 3 endogenous and 1 latent variable. The linear system connecting random variables writes as

$$\begin{cases} \xi = \gamma_1 X_1 + \gamma_2 X_2 + \gamma_3 X_3 + \varepsilon_0 \\ Y_1 = \lambda_1 \xi + \varepsilon_1 \\ Y_2 = \lambda_2 \xi + \varepsilon_2 \\ Y_3 = \lambda_3 \xi + \varepsilon_3 \end{cases}$$

Here $X_{1,2,3}$ are exogenous variables, $Y_{1,2,3}$ are endogenous variables, ξ is a latent variable, $\varepsilon_{0,1,2,3}$ are Gaussian noises and $\gamma_{1,2,3}$, $\lambda_{1,2,3}$ are proportionality coefficients. We also introduce $\theta_i = \backslash\mathrm{VV}\varepsilon_i, i = 0,1,2,3$.

Suppose we are given some experimental data, which consists of 6 samplings for $X_{1,2,3}$ and $Y_{1,2,3}$. Note that latent variable ξ remains unobserved. With this data, we can estimate covariance matrix $S \in \backslash\mathrm{RR}^{6\times 6}$. On the other hand, we can compute caovariance matrix $C = C(\gamma_{1,2,3}, \lambda_{1,2,3}, \theta_{0,1,2,3})$, which is induced by model (???). Model parameters are determined as the solution of the following optimization problem:

$$F(S, C) = Tr(SC^{-1}) + \log\det(C^{-1}) \to \min\ s.t.\ C = C(\gamma_{1,2,3}, \lambda_{1,2,3}, \theta_{0,1,2,3})$$

After model parameters are found, the quality of the model can be estimated as

$$Q(S) = \frac{\backslash\mathrm{VV}\{\gamma_1 X_1 + \gamma_2 X_2 + \gamma_3 X_3\}}{\backslash\mathrm{VV}\{\gamma_1 X_1 + \gamma_2 X_2 + \gamma_3 X_3 + \varepsilon_0\}}$$

In this work, we have a large pool ($\sim$4000) of samplings for different random variables (with economical meanings). We aim at finding a set of 3 exogenous and 3 endogenous variables, for which the quality of the model Q will be the largest.

D.O. Selikhanovych

Comparison of variations of the linear coupling method

The paper compares the methods of linear coupling and APDLSGD, proposed in [1] and [2] respectively. The modeling of the algorithms was carried out using the example of a quadratic programming problem with a positive definite symmetric matrix, considered in part 1 of exercise 1.3 of the manual [3] and proposed by Yu.E. Nesterov [4].

[1]. Allen-Zhu Z., Orecchia L. Linear Coupling: An Ultimate Unification of Gradient and Mirror Descent // https://arxiv.org/pdf/1407.1537v4.pdf

[2]. Nesterov Y., Gasnikov A., Guminov S., Dvurechensky P. Primal-dual accelerated gradient descent with line search for convex and nonconvex optimization problems // https://arxiv.org/pdf/1809.05895.pdf

[3]. Gasnikov A.V. Modern numerical optimization methods. The method of universal gradient descent: a tutorial / A.V. Gasnikov. -M.: MIPT, 2018. - 181 p. - Ed. 2nd, add.

[4]. Nesterov Yu.E. Introduction to convex optimization. -M.: ICNMO, 2010

A. Titov

A. Ivanova, M. Alkousa,
F. Stonyakin, A. Gasnikov

One method for convex optimization problems with non-smooth strongly convex constraint

Many inverse problems lead us to consider ill-posed problems with functional constraints. From the point of view of the numerical method, in general case, it is impossible to achieve the convergence in the argument for such class of problems.

According to the https://arxiv.org/ftp/arxiv/papers/1711/1711.00394.pdf (see task 5.6) we consider some special class of constraint optimization problems for which, under certain conditions, it is sufficient to regularize only the restriction. In the general case, the objective functional is not strongly convex and smooth.

Our report is devoted to a special approach for convex minimization problem with some non-smooth strongly convex inequality constraint, which turns into the equality at the exact solution point. Taking into account the strong convexity of the constraint we show that the problem of the considered class can be solved in linear time with a given accuracy. In case of a large number of strongly convex non-smooth constraints, we can consider one max-type constraint,which will also be strongly convex. It allows us to use the proposed method for problems with many restrictions.

A. Agafonov

General scheme for estimating the rate of convergence in the strongly convex case

In this paper we consider convex optimization problem. We introduce (δ, L, μ) model of strongly convex function f(x) (regarding prox). It can be seen as an extension of (δ, L) model from A.Gasnikov's book [Современные численные методы оптимизации] and (δ, L, μ) oracle from O.Devolder's CORE discussion paper. In this paper we consider mirror descent method as in §3 A.Gasnikov's book. We prove that this method works faster on strongly-convex functions than on non-strongly convex. Strong convexity leads to fast convergence rates (exponential instead of polynomial for non-strongly functions). Our theoretical bounds are supported by numerical results.

D. Dvinskikh

Computation of non-regularized Wasserstein barycenter using KL prox-structure

We solve the problem of computation Wasserstein barycenter of a set of discrete probability measures. We calculate the non-regularized barycenter without entropy smoothing by using Kullback-Leibler proximal gradient algorithm. We use Iterative Bregman Projection method for solving inner problem on each iteration of proximal KL gradient descent.

FOR NOTES

FOR NOTES

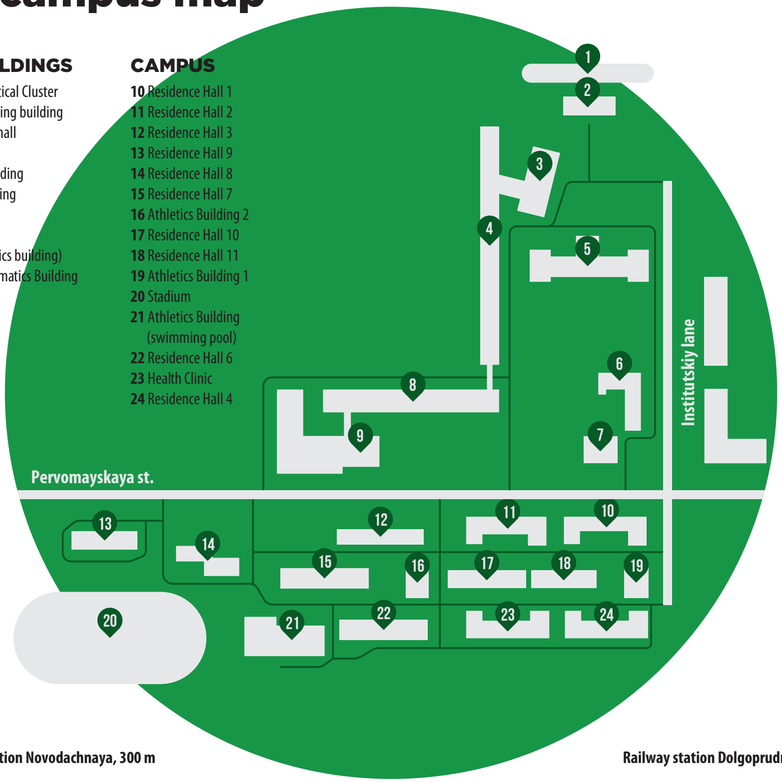
MIPT buildings and campus map

MIPT BUILDINGS

1 Biopharmaceutical Cluster
2 Radio Engineering building
3 Main building hall
4 Main building
5 Laboratory building
6 Audience building
7 Dining Hall
8 New building (Microelectronics building)
9 Applied Mathematics Building

CAMPUS

10 Residence Hall 1
11 Residence Hall 2
12 Residence Hall 3
13 Residence Hall 9
14 Residence Hall 8
15 Residence Hall 7
16 Athletics Building 2
17 Residence Hall 10
18 Residence Hall 11
19 Athletics Building 1
20 Stadium
21 Athletics Building (swimming pool)
22 Residence Hall 6
23 Health Clinic
24 Residence Hall 4



← **Railway station Novodachnaya, 300 m**

Railway station Dolgoprudnaya, 750 m →