QIPA

30 NOV 2020
02 DEC 2020

Quasilinear Equations, Inverse Problems and Their Applications

Conference handbook and proceedings

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The Eurasian Association on Inverse Problems (EAIP)
Moscow Institute of Physics and Technology (MIPT)
Faculty of Applied Mathematics and Control of MIPT
Ecole Polytechnique
Phystech School of Applied Mathematics and Informatics

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QIPA2020: Monday, November 30

9:30: **Welcome**

PLENARY SESSİON

Chair: R.G. Novikov

10:00: **T. Hohage** (Georg-August-Universität Göttingen, Germany)
Imaging from correlation data: uniqueness results and iterative algorithms

10:40: **A. Hasanoglu** (Kocaeli University, Türkiye)
Spatial load reconstruction in a vibrating elastic plate from boundary observation

11:20: **A. Mironov,** G. Mauleshova (Sobolev Institute of Mathematics, Novosibirsk State University, Russia)
One-point commuting difference operators

12:00: **I.A. Taimanov** (MI SB RAS, Russia)
Quasiclassical approximation for magnetic monopoles

12:40: Lunch

Session «Inverse problems and tomography»

Chair: A. Jollivet

14:00: **V. Sharafutdinov** (Sobolev Institute of Mathematics, Russia)
Radon transform on Sobolev spaces

14:40: **L. Pestov** (IKBFU Russia)
On inverse coefficient problem for the acoustic wave equation

15:20: **G. Mercier** (University of Vienna , Austria), J. Iglesias (Radon Institute for Computational and Applied Mathematics, Austria)
Convergence of level sets in total variation denoising without source condition

16:00: **M.A. Shishlenin** (Novosibirsk State University, Russia)
Coefficient inverse acoustic problems and conservation laws

16:40: O. Krasulin, **A.S.Shurup** (Department of acoustics, Faculty of Physics, M.V.Lomonosov Moscow State University)
Numerical investigation of iterative approach for acoustic tomography problems

17:20: R. Novikov (Ecole Polytechnique, France), **V. Sivkin** (Lomonosov MSU, Russia)
Error estimates for phase recovering from phaseless scattering data

18:00: **V. Filatova** (Immanuel Kant Baltic Federal University, Russia)
Medical ultrasound tomography problem: processing of real data

Session «Numerical methods»

Chair: I.B. Petrov

14:00: **V. Aksenov** MIPT, Russia); A. Vasyukov (MIPT, Russia); K. Beklemysheva (MIPT, Russia)
Acquiring the compliance tensor from the vibrational testing data for a 2D composite structure

14:40: **P. Chuprov** (MIPT, ICAD RAS Russia); P. Utkin (ICAD RAS, Russia)
Numerical study of combustion waves in heterogeneous explosive using Baer-Nunziato model

15:20: **K.E. Beklemysheva** (MIPT, Russia)
Numerical modeling of impact loading and residual strength of fiber-metal laminates with grid-characteristic numerical method

16:00: **A. Favorskaya** (MIPT, Russia); N. Khokhlov (MIPT, Russia); V. Stetsyuk (MIPT, Russia); I. Mitskovets (MIPT, Russia)
About the grid-characteristic method using Chimera meshes

16:40: **A. Lobanov** (MIPT, Russia); I. Basharov (MIPT, Russia)
On the finite difference schemes construction for solvind Burgers equation

17:20: **I. Mitskovets** (MIPT, Russia); S. Vladislav (MIPT, Russia)
Modeling the propagation of wave disturbances in a realistic geological problem using the grid characteristic method with overset grid approach

18:00: **A. Vasyukov** (MIPT, Russia)
Modeling soil deformation during permafrost thawing

18:40: I. Mitskovets (MIPT, Russia); **N. Khokhlov** (MIPT, Russia); V. Stetsyuk (MIPT, Russia)
Comparison of interpolation algorithms for overset grid approach and grid-characteristic method

Session «Mathematical modeling»

Chair: A.A.Shananin

14:00: **L.A. Beklaryan** (CEMI RAS, Russia)
On the existence of periodic and bounded soliton solutions for systems with strongly nonlinear potentials

14:40: **A.S. Bratus** (Russian University of Transport, Russia)
Continual models of hypercycling and autocatalytic equation for macromolecules replication

15:20: **V.N. Razzhevaikin** (Federal Research Centre “Computer Science and Control” of RAS, Russia)
Multicomponent Gause principle in models of biological communities and other problems of asymptotic behavior in Volterra-like systems

16:00: **N. Petrosyan** (MSUT "STANKIN", Russia)

On the asymptotic behavior of the solution of the Cauchy problem for a quasilinear first order equation

16:40: **O.S. Rozanova** (MSU, Russia)
Exact thresholds in the cold plasma behaviour

17:20: **E. Shifrin** (MIPT, Russia)
About visualization of a viscous incompressible liquid by solid particles

18:00: **A.A. Skubachevskii** MIPT, Russia); V. Lapshin (MSU, Russia)
Charged particles in the field of an inhomogeneous electromagnetic wave

18:40: **N. Trusov** (Moscow State University, Russia)
Numerical study of the stock market crises based on mean fied games approach

19:20: **L.V. Egorov** (Moscow State University, Russia)
Asymptotics of the QE Cauchy problem solution in the new technologies diffusion modeling

QIPA2020: Tuesday, December 1

PLENARY SESSİON

Chair: A. Mironov

10:00: **S.I. Kabanikhin** (ICM&MG SB RAS, Russia)
Inverse Problems of Epidemiology

10:40: **R.G. Novikov** (Ecole Polytechnique, France)
Monochromatic inverse scattering

11:20: **A. Laptev** (Imperial College London, UK)
Magnetic rings

12:00: **P.G. Grinevich** (Steklov Mathematical Institute, Russia), P. M. Santini (University of Roma "La Sapienza", Italy)
Unstable modes near NLS Akhmediev breather

12:40: Lunch

Session « Inverse problems and computations»

Chair: L. Pestov

14:00: **A.Yagola** (Lomonosov MSU, Russia)
Numerical methods for 3D image surfacing imaging with backscattered electron detectors

14:40: A.B. Bakushinsky (Federal Research Center “Computer Science and Control” of RAS, Institute for Systems Analysis, Russia), **A.S. Leonov** (National Nuclear Research University ’MEPHI’, Russia)
Fast numerical solution of a three-dimensional multi-frequency inverse acoustic problem in a cylindrical domain

15:20: **A.S. Fomochkina**, B.G. Bukchin (IEPT RAS, Russia)
Identification of the fault plane in the inverse problem of determining the source of earthquakes

16:00: **A. V. Lapin** (Kazan Federal University, Russia)
Numerical solution of a time-fractional one-phase Stefan problem

16:40: **N.Y. Chernikova** (RUDN University, Russia)
A numerical optimization method in the problem of comparing the spatial structure of molecules in a crystal

Session «Numerical methods»

Chair: N. Khokhlov

14:00: **P. Stognii** (MIPT, Russia)
The influence of the methane bombs on the process of hydrocarbon deposits detection

14:40: **V. Golubev** (MIPT, Russia), A. Borisova (MIPT, Russia); V. Petrukhin (PAO Sberbank, Russia); A. Shevchenko (MIPT, Russia)
The simulation of anisotropic elastic media with the grid-characteristic method

15:20: **F. Sergeev**(MIPT, Russia), I. Petrov (MIPT, Russia), M. Muratov (MIPT, Russia)
Computer simulation of dynamic processes in industrial ice structures

16:00: M.V. Muratov (MIPT, Russia), **D. Konov** (MIPT, Russia); V. Biryukov (MIPT, Russia)
The solution of Stefan problem for seasonal phase changes of ice islands

16:40: **M. Muratov** (MIPT, Russia), I.B. Petrov (MIPT, Russia)
Exploration seismology inverse problems solution by methods of machine learning

17:20: M.Muratov (MIPT, Russia), **V. Ryazanov** (MIPT, Russia)
Inverse problems of fractured layers exploration seismology solution with use of convolutional neural networks

18:00: **E. Pesnya,** A. Kozhemyachenko, A. Favorskaya (MIPT, Russia)
Implicit methods in modeling of linear-elastic body

18:40: A.I. Lopato (MIPT, ICAD RAS, Russia), **Ya. Poroshyna** (MIPT , ICAD RAS, Russia), P.S. Utkin (MIPT, ICAD RAS, Russia)
Numerical simulation of shock wave propagation in the non-uniform media in the shock-attached frame

19:20: **M. Seleznov** (MIPT, Russia), A. Vasyukov (MIPT, Russia)
Solving problems of the strength of a thin thread by machine learning methods

20:00: **M.S. Stankevich** (MIPT, Russia)
Using convolutional neural networks for inverse problems of boundary

location in heterogeneous medium

Session «Optimization Methods for Inverse Problems »

Chair: A.Yu. Gornov

14:00: **N. Tupitsa** (MIPT, IITP RAS , Russia)
Multimarginal optimal transport by accelerated alternating minimization

14:40: **P. Dvurechensky** (Weierstrass Institute for Applied Analysis and Stochastics, Germany), A. Gasnikov (MIPT, Russia); A. Kroshnin(MIPT, Russia)
On the complexity of optimal transport problems

15:20: **A. Rogozin** (MIPT, Russia)
Decentralized solution of saddle point problems

16:00: **E.L. Gladin** (MIPT, Skoltech, Russia)
Approaches to solving convex-concave saddle point problems

16:40: **A.V. Gasnikov** (MIPT, Russia)
Accelerated local SGD

17:20: **A. Titov** (MIPT, Russia), F. Stonyakin (CFU, MIPT, Russia); M. Alkousa (MIPT, Russia); S. Ablaev (CFU, Russia); A. Gasnikov (MIPT, Russia)
Mirror descend methods for relatively Lipschitz-continuous stochastic convex programming problems

18:00: **A.V. Ogaltsov** (HSE, Russia)
Adaptive gradient descent for convex and non-convex stochastic optimization

QIPA2020: Wednesday, December 2

PLENARY SESSİON

Chair: A. Hasanoglu

9:00: **M.V. Klibanov** (University of North Carolina at Charlotte, USA)
Carleman estimates for globally convergent numerical methods for coefficient inverse problems

9:40: **A.A. Shananin** (MIPT, Russia)
The Yang`s duality and its application to the aggregation of the balances

10:20: **L. Baratchart** (INRIA, Sophia Antipolis, France), D. Hardin (Vanderbilt University, USA), C. Villalobos-Guillén (Ecole Polytechnique, France)
Inverse potential problems in divergence form and divergence free measures in the plane

11:00: **H. Haddar** (INRIA, France), F. Cakoni (Rutgers University, USA); D. Colton (University of Delaware, USA)
Duality between scattering poles and interior transmission problems

11:40: **R.A. Chertovskih** (University of Porto, Portugal), V.A. Zheligovsky (IEPT RAS, Russia)
Does the alpha-effect exist?

12:20: Lunch

Session «Spectral theory and inverse problems»

Chair: M.A. Shishlenin

13:30: **M.I. Belishev** (St. Petersburg Department of Steklov Mathematical Institute, Russia)
Electric impedance tomography problem for nonorientable surfaces

14:10: **E.L. Korotyaev** (St.-Petersburg State University, Russia),
Inverse spectral theory for perturbed torus

14:50: **A. Jollivet** (CNRS & Université de Lille France)
On a first variation formula for the Steklov zeta function of a smooth planar domain

15:30: **K.B. Sabitov** (Sterlitamak branch of the Institute for Strategic Studies of the Republic of Bashkortostan , Sterlitamak branch of Bashkir State University, Russia)
Inverse problems for the equation of oscillations of a rectangular plate to find the source

16:10: **M. Ismailov** (Gebze Technical University, Turkey)
Borg - type uniqueness theorem for first - order hyperbolic system on half-axis

16:50: **M.M. Malamud** (Peoples Friendship University of Russia)
Inverse spectral problems for first order systems of ordinary differential equations

17:30: **A. Badanin** (St.-Petersburg State University, Russia)
Hill's equations with the potentials analytically dependent on energy

18:10: **N. Saburova** (Northern (Arctic) Federal University, Russia)
Trace formulas for Laplacians on periodic discrete graphs

Session «Integrable systems and nonlinear analysis»

Chair: S.I. Kabanikhin

13:30: **A.V. Arutunov,** S.E.Zhukovskiy (IPU RAS)
On variational principles in nonlinear analysis

14:10: **V.S. Dryuma** (IMI RM, Moldova)
On the Ricci-flat metric in the theory of Navier-Sokes equations and its applications

14:50: **L.V. Bogdanov** (Landau Institute for Theoretical Physics, Russia)
Matrix extensions of dispersionless integrable systems and Bogomolny

equations on an Einstein-Weyl geometry background

15:30: **M. Pavlov** (FIAN, Russia)
Multi-dimensional integrable Lagrangian systems

16:10: A.S. Mikhaylov, **V.S. Mikhaylov** (PDMI RAS, Russia)
Toda lattice for semi-bounded initial data and classical moment problem

16:50: **A.S. Demidov** (Moscow State University, Russia)
On numerically realizable explicit formulas for solutions of 2- and 3-dimensional equations $div(\alpha\nabla\omega) = 0, div(\beta(\omega)\nabla\omega) = 0$ with Cauchy analytic data on the analytic boundary.

17:30: **M.V. Balashov** (IPU RAS)
Weakly convex functions and the quadric growth condition

18:10: **A.Faminskii** (Peoples Friendship University of Russia)
On inverse problems with integral overdetermination for the Korteweg-de Vries equation

Session «Optimization Methods for Inverse Problems»

Chair: A.V. Gasnikov

13:30: **E. Kotliarova** (MIPT, Russia)
Two-stage model of equilibrium distributions of traffic flows

14:10: **A.Yu. Gornov** (IDSTC RAN, Russia)
Алгоритмы решения унимодальных задач безусловной оптимизации

14:50: **A.B. Ryabtsev** (MIPT, Russia)
The error accumulation in the conjugate gradient method for degenerate problem

15:30: **A. Anikin** (IDSTC RAN, Russia)
Parallel computing technologies in finite-dimensional optimization problems

16:10: **E. Gorbunov** (MIPT, Russia); D. Kovalev (KAUST, Saudi Arabia); P. Richtárik (KAUST, Saudi Arabia)
Towards new distributed methods with error feedback and delayed updates

16:50: **F.S. Stonyakin** (V. Vernadsky Crimean Federal University, MIPT, Russia)
Non-smooth convex programming problems: inexactness and relative accuracy

17:30: **A. Sadiev** (MIPT, Russia), A. Beznosikov (MIPT, Russia); A. Gasnikov (MIPT, Russia)
Gradient-free methods with inexact oracle for convex-concave stochastic saddle-point problem

19:00: **Closing Meeting**

TALKS

A. Hasanoglu

Simultaneous identifying the thermal conductivity and radiative coefficient in heat equation fromboundary Dirichlet and Neumann boundary measured outputs

In this paper we study the
inverse coefficient problem of simultaneous identifying
the thermal conductivity $k(x)$ and radiative coefficient $q(x)$ in

$$\begin{cases} u_t(x,t) = (k(x)u_x(x,t))_x - q(x)u, ((x,t) \in \Omega_T := (0,\ell) \times (0,T] \\ u(x,0) = 0, 0 < x < l, \\ u(0,t) = 0, k(\ell)u_x(\ell,t) = f(t), 0 < t < T \end{cases} \quad (1)$$

from the most available Dirichlet and Neumann boundary measured outputs (temperature and flux):

$$\begin{cases} v(t) := u(\ell,t) \\ \varphi(t) := -k(0)u_x(0,t) \\ t \in [0,T] \end{cases} \quad (2)$$

We introduce the Neumann-to-Dirichlet and Neumann-to-Neumann operators and derive properties of these operators. The results allow us to prove existence of a quasi-solution of the inverse coefficient problem (1) – (2). The approach proposed here can be used also for derivation of the Fr\'{e}chet gradient of the Tikhonov functional which is an important issue.

A. Mironov, G. Mauleshova

One-point commuting difference operators

We consider one-point commuting difference operators of rank one. The coefficients of these operators depend on a functional parameter, shift operators being included only with positive degrees. We study these operators in the case of hyperelliptic spectral curve when the marked point coincides with the branch point. We construct examples of operators with polynomial and trigonometric coefficients. Moreover, difference operators with polynomial coefficients can be embedded in the differential ones with polynomial coefficients. This construction provides a new way of constructing commutative subalgebras in the first Weyl algebra

I.A. Taimanov

Quasiclassical approximation for magnetic monopoles

A quasiclassical approximation is constructed to describe the eigenvalues of the magnetic Laplacian on a compact Riemannian manifold in the case when the magnetic field is not given by an exact 2-form. For this, the multidimensional WKB method in the form of Maslov canonical operator is applied. In this case, the canonical operator takes values in sections of a nontrivial line bundle (based on the joint work with Yu.A. Kordyukov).

V. Sharafutdinov

Radon transform on Sobolev spaces

The Reshetnyak formula states that $\|f\|_{L^2(R^n)} = \|Rf\|_{H^{(n-1)/2}_{(n-1)/2}(S^{n-1}\times R)}$, where R is the Radon transform and $\|\cdot\|_{H^{(n-1)/2}_{(n-1)/2}(S^{n-1}\times R)}$ is some special norm. The formula allows to extend the Radon transform to a bijective isometry of Hilbert spaces $R: L^2(R^n) \to H^{(n-1)/2}_{(n-1)/2,e}(S^{n-1} \times R)$. For any real r, s and for any $t > -n/2$, we introduce Sobolev type spaces $H^{(r,s)}_t(R^n)$ and $H^{(r,s)}_{t,e}(S^{n-1} \times R)$ and prove the following version of the Reshetnyak formula: $\|f\|_{H^{(r,s)}_t(R^n)} = \|Rf\|_{H^{(r,(s+n-1)/2)}_{t+(n-1)/2}(S^{n-1}\times R)}$. The formula allows to extend the Radon transform to a bijective isometry of Hilbert spaces $R: H^{(r,s)}_t(R^n) \to H^{(r,s+(n-1)/2)}_{t+(n-1)/2,e}(S^{n-1} \times R)$. In the case of integer $r \geq 0$ and $s \geq 0$, the space $H^{(r,s)}_{t,e}(S^{n-1} \times R)$ consists of even functions $\varphi(\xi, p)$ which have quadratically integrable derivatives of order $\leq r$ with respect to the ξ-variable and of order $\leq s$ with respect to the p-variable.

G. Mercier, J. Iglesias

Convergence of level sets in total variation denoising without source condition

We present some results of geometric convergence of level sets for solutions of total variation denoising as the regularization parameter tends to zero. The common feature among them is that they make use of explicit constructions of variational mean curvatures for general sets of finite perimeter. Consequently, no additional regularity of the level sets of the ideal data is assumed, but other restrictions on it or on the noise are required.

M.A. Shishlenin

Coefficient inverse acoustic problems and conservation laws

The inverse problem for hyperbolic system of the equations is considered. Numerical methods is based on the minimizing of cost functional. Theoretical and numerical results are presented. The research was supported by Russian Science Foundation (project no. 19-11-00154).

O. Krasulin, A.S.Shurup

Numerical investigation of iterative approach for acoustic tomography problems

Results of numerical modeling of iterative approximate reconstruction algorithm proposed in [1] are considered. Reconstruction results for complex-valued scatterers are compared with estimates obtained by using non-iterative functional algorithm [2-3], numerically implemented before [4]. Perspectives of the considered iterative approach in acoustic tomography problems are discussed. The reported study was funded by RFBR and CNRS, project number 20-51-15004. 1. Novikov R.G. An iterative approach to non-overdetermined inverse scattering at fixed energy // Sbornik: Mathematics. 2015. V. 206. N 1. P.120-134. https://hal.archives-ouvertes.fr/hal-00835735 2. Novikov R.G. Rapidly converging approximation in inverse quantum scattering in dimension 2 // Physics Letters A. 1998. V. 238. N 2–3. P. 73–78. 3. Novikov R.G., Santacesaria M. Monochromatic reconstruction algorithms for two-dimensional multi-channel inverse problems // International Mathematics Research Notices. Oxford University Press (OUP). 2013. N. 6. P. 1205-1229. https://hal.archives-ouvertes.fr/hal-00594674 4. Burov V.A., Shurup A.S., Zotov D.I., Rumyantseva O.D. Simulation of a functional solution to the acoustic tomography problem for data from quasi-point transducers // Acoustical Physics. 2013. V. 59. N 3. P. 345–360.

R. Novikov, V. Sivkin

Error estimates for phase recovering from phaseless scattering data

We studied the simplest explicit formulas for approximate finding the complex scattering amplitude from modulus of the scattering wave function. We obtained detailed error estimates for these formulas in dimensions d = 2, 3.

V. Aksenov, A. Vasyukov, K. Beklemysheva

Acquiring the compliance tensor from the vibrational testing data for a 2D composite structure

The authors report their first results on the problem of reconstructing the components of elastic tensor of a composite material from amplitude-frequency characteristic of a specimen, availiable from experiments. During the production processes composite material may change its elastic properties that are important for the resulting detail. Thus, it’s desirable to have the technique to obtain the elastic parameters of the material of the final sample having complex geometry. The work utilizes a finite-element model of thin composite structures which is being developed by the authors. The model supports complex geometries along with arbitrary anisotropy of the material. This custom code is used along with semi-analytical procedures to speed up the computations. The role of damping in the experimental installation is also studied. Reconstruction is attempted from data generated numerically as well as from the actual experimental data. We also consider the possibility to substitute densely perforated parts with solid parts with effective compliance tensor that provides the same frequency properties. Such procedure will allow for usage of coarser computational grids, thus speeding up the practical computations

P. Chuprov, P. Utkin

Numerical study of combustion waves in heterogeneous explosive using Baer-Nunziato model

The work is dedicated to the numerical study of the deflagration wave propagation along the gun powder charge. Mathematical model is bases on the hyperbolic Baer-Nunzizato system of equations and takes into account mass, impulse and heat interphase exchange as well as the compaction of the solid phase of powder particles. Statement of the problem corresponds to the full-scale experiment. The process is analyzed in terms of curves on the pressure transducers along the charge.

K.E. Beklemysheva

Numerical modeling of impact loading and residual strength of fiber-metal laminates with grid-characteristic numerical method

The Grid-Characteristic numerical Method (GCM) allows to implement complex border and contact conditions, including the non-reflecting border and the destructible contact. Both this conditions are very important for the precise and effective modeling of Low-Velocity Impacts (LVI) on fiber and Fiber-Metal Laminates (FML) and the resulting Barely Visible Impact Damage (BVID) that influences the residual strength of a composite aircraft part. BVID is the type of damage that is not visible by the naked eye and can be hardly detected by a standard ultrasound equipment that is used for regular maintenance. It can appear during any weak impacts like bird strike or hail. Determining its influence on the residual strength of the part is very important to define the priorities of development of ultrasound diagnostics. In this research, the GCM was applied for a full cycle of loading of an FML aircraft cover part. The FML consisted of a Carbon Fiber Reinforced Polymer (CFRP) and a single titanium layer on the upper surface. The cycle of loading in a single calculation consisted of an LVI caused by a small striker and a comparatively slow compressive in-plane loading. Three-dimensional patterns of velocity and stress distributions over the time of calculation are given. Destruction patterns, obtained via the Hashin failure criterion are given and analyzed.

A. Favorskaya,N. Khokhlov, V. Stetsyuk, I. Mitskovets

About the grid-characteristic method using Chimera meshes

Exploration and refinement of hydrocarbon reserves require the development of methods for processing seismic data, which is reduced to solving the inverse problem. The efficient solution of inverse problems requires the development of novel and efficient computational methods for solving the corresponding direct problems. In many ways, the useful properties of the field depend on the characteristics of fracturing zone. Therefore, it is important to have high-precision numerical methods for calculating wave phenomena in fractured media, which save computing resources. We introduce a novel modification of the grid-characteristic method on Chimeric computational meshes. Also, this method allows to take into account the features of the surface topology. This work has been performed with the financial support of the Russian Science Foundation (project No. 20-71-10028).

A. Lobanov, I. Basharov

On the finite difference schemes construction for solvind Burgers equation

The new method of the difference schemes for solving the Burgers equation constructing is discovered. The method is based on the two divergent forms for the Hopf equation. To search for the optimal difference schemes in this family, an analysis in the space of insufficient coefficients was applied using the technique of self-dual problems of linear programming solving. The multiple before the third derivative of exact solution grid mapping is used as a tar-get functional. It is necessary and sufficient that the complementary slackness conditions be fulfilled. Based on complementary slackness conditions analysis, a new version of the Lax–Wendroff scheme was built. The new hybrid schemes with maximum anti-dispersion also were constructed. Some numerical results demonstrate the properties of the new difference schemes. Such a consideration opens up a way to build the optimal hybrid schemes with a successful choice of the target functional linear by the scheme insufficient coefficients

I. Mitskovets, S. Vladislav

Modeling the propagation of wave disturbances in a realistic geological problem using the grid characteristic method with overset grid approach

This work demonstrates the applicability of the grid characteristic method in combination with the overset grid approach for solving a realistic problem statement of modeling the propagation of wave disturbances near the soil surface. And also explains the benefits of this approach. This work has been performed with the financial support of the Russian Science Foundation (project No. 20-71-10028).

A. Vasyukov

Modeling soil deformation during permafrost thawing

The report is devoted to modeling of soil behavior during permafrost thawing. For these calculations, the input parameters are information on the phase composition of the medium obtained from third-party calculations of the processes of thawing of a multiphase medium. These parameters are used to solve a mechanical problem in which a multiphase medium is replaced by a medium with continuously distributed effective mechanical characteristics that depend on the phase composition at a given point in space. When permafrost thaws, a change in mechanical characteristics can lead to such consequences as weakening of the adhesion of soil layers to each other or the formation of macroscopic cavities and inhomogeneities. This in turn can lead to catastrophic destruction of buildings and structures.

I. Mitskovets, N. Khokhlov, V. Stetsyuk

Comparison of interpolation algorithms for overset grid approach and grid-characteristic method

In this work a comparison of various interpolation algorithms used for transferring modelling results between grids is presented. Also the way of adapting the discrete natural neighbour interpolation for irregular meshes is shown. The impact of interpolation accuracy on the overall modelling results is analyzed. This work has been performed with the financial support of the Russian Science Foundation (project No. 20-71-10028).

L.A. Beklaryan

On the existence of periodic and bounded soliton solutions for systems with strongly nonlinear potentials

There is a one-to-one correspondence between bounded and periodic soliton solutions of the original system and bounded and periodic solutions of the induced functional-differential equation of pointwise type. In turn, conditions are established under which bounded and periodic solutions of a functional differential equation of pointwise type with a strongly nonlinear right hand side turn out to be solutions of the overdetermined functional differential equation of pointwise type with a quasilinear right hand side for which there are corresponding theorems on the existence of a bounded and periodic solution.

A.S. Bratus, O. Chmyreva

Continual models of hypercycling and autocatalytic equation for macromolecules replication

The continual models of hypercycling and autocatalytic replication are considered. Existence and stability of stationary solutions are study. For some parameters value it is proved existence of stable spatially nonuniform solutions.

V.N. Razzhevaikin

Multicomponent Gause principle in models of biological communities and other problems of asymptotic behavior in Volterra-like systems

A generalization for Gause’s principle of competitive exclusion, which guarantees the disappearance of at least one species in a community with a species number that exceeds the number of resources is proposed. It has the form of theorems revealing the disappearance of at least n – m components in a finite-dimensional system of differential equations that simulates the dynamics of a community with n species in a rough case, provided that the Malthusian vector-valued function assumes values on the hyperplane of the dimension m, which does not contain the origin. Other problems of asymptotic behavior for component-wise subdevided systems are also considered. The relationship of the constructed theory with Lotka-Volterra type systems is discussed.

N. Petrosyan

On the asymptotic behavior of the solution of the Cauchy problem for a quasilinear first order Equation

The generalized entropy solution (in the sense of Kruzhkov) of the Cauchy problem for a quasilinear scalar first-order conservation law $u_t + f(u_x) = 0$ with a measurable bounded initial data and non-convex flux function f is considered in the upper half-plane. It is proved for the initial data with a compact support that the solution $u(t, x)$ tends to zero as time t tends to infinity uniformly in xx under the assumption $f''(0) \neq 0$.

O.S. Rozanova

Exact thresholds in the cold plasma behaviour

We consider the Cauchy problem for quasilinear hyperbolic system arising in the colisionless plasma theory. In particular, we study a possibility of existence of a global in time smooth solution, the character of the blowup, the influence of electron-ion collisions and the difference in oscillations in one, two and three dimensions.

E. Shifrin

About visualization of a viscous incompressible liquid by solid particles

Рассматривается метод визуализации течений вязкой несжимаемой жидкости шаровыми маркерами радиуса той же плотности. Существование и единственность взаимосвязанного движения маркера и окружающей жидкости следует из теоремы А.Такахаши. Визуализация основана на Гипотезе о сходимости последовательности траекторий центров R-маркеров к траектории жидкой частицы при R, стремящимся к нулю . Доказывается, что визуализация невозможна, так как маркировка сопровождается не исчезающими возмущениями потока .

A.A. Skubachevskii, V. Lapshin

Charged particles in the field of an inhomogeneous electromagnetic wave

Using an example of an inhomogeneous electromagnetic wave created by a superposition of two plane monochromatic electromagnetic waves arbitrarily directed with respect to each other, an approach that makes it possible to simulate a wide spectrum of electromagnetic waves is demonstrated. The complete system of equations that describe the motion of an electron in an inhomogeneous electromagnetic field is numerically solved. The features of the trajectory and spectrum of the electron radiation were discovered and investigated.

N. Trusov

Numerical study of the stock market crises based on mean fied games approach

We present an approach to describe the stock market crises based on Mean Field Games (MFGs) and Optimal Control theory with a turnpike effect. The impact of the large amount of high-frequency traders can be modelled via mean field term. We introduce the turnpike as a function that relies on the changes of the asset share price. A MFG is a coupled system of PDEs: a Kolmogorov-Fokker-Planck equation, evolving forward in time and a Hamilton-Jacobi-Bellman equation, evolving backwards in time. The ill-posedness of this system comes from a turnpike effect. We present the numerical solution of an extremal problem that is dual to PDEs system. We apply this approach to describe the Chinese stock market crash in 2015 considering the representative stock of CITIC Securities (ticker 600030). The work has been supported by RFBR (grant 20-07-00285).

L.V. Egorov

Asymptotics of the QE Cauchy problem solution in the new technologies diffusion modeling

A few modifications of the transition to a new technological level in the schumpeterian dynamics models are considered. The asymptotic behavior of the Cauchy problem solutions of the corresponding quasilinear equations and their differential-difference analogues is studied, which allows us to characterize the new technologies diffusion structure.

S.I. Kabanikhin

Inverse Problems of Epidemiology

Different models of epidemic spread are considered including deterministic, stochastic and multicomopnent. Theory of numerics of inverse problems are discussed.

R.G. Novikov

Monochromatic inverse scattering

We give a short review of old and recent results on monochromatic inverse scattering. Our considerations include reconstruction from far and from near field scattering data. This talk is based, in particular, on references [1]-[3]. References [1] R.G. Novikov, Multidimensional inverse spectral problem for the equation $-\Delta\psi + \big(v(x) - Eu(x)\big)\psi = 0$, Funct. Anal. Appl. 22, 263-272 (1988) [2] A.D. Agaltsov, T. Hohage, R.G. Novikov, Monochromatic identities for the Green function and uniqueness results for passive imaging, SIAM J. Appl. Math. 78(5), 2865-2890 (2018) [3] R.G. Novikov, Multidimensional inverse scattering for the Schrödinger equation, https://hal.archives-ouvertes.fr/hal-02465839v1

P.G. Grinevich, P. M. Santini

Unstable modes near NLS Akhmediev breather

We calculate the unstable modes for linearised NLS equation near Akhmediev breather in terms of derivatives of squared eigenfunctions with respect to the spectral parameter.

A.Yagola, E. Rau, D. Lukyanenko, A. Borzunov

Numerical methods for 3D image surfacing imaging with backscattered electron detectors

We propose a new SFS (shape from shading) technique for improved 3D surface reconstruction and imaging of relatively smooth surface topography using the scanning electron microscope (SEM). Reference. A.A. Borzunov, V.Y Karaulov, N.A. Koshev, D.V. Lukyanenko, E.I. Rau, A.G. Yagola, S.V. Zaitsev. 3D surface topography imaging in SEM with improved backscattered electron detector: arrangement and reconstruction algorithm. – Ultramicroscopy, 2019, v. 207, published online, pp. 1-9, https://doi.org/10.1016/j.ultramic.2019.112830

A.B. Bakushinsky, A.S. Leonov

Fast numerical solution of a three-dimensional multi-frequency inverse acoustic problem in a cylindrical domain

A new algorithm is proposed for solving a three-dimensional scalar inverse problem of acoustic sounding of an inhomogeneous medium in a cylindrical region. The data of the problem are measurements of the complex amplitude of the wave field “in the cylindrical domain” outside the inhomogeneity region. The inverse problem can be reduced to solving a set of one-dimensional Fredholm integral equations of the first kind, to the subsequent calculation of the complex amplitude of the wave field in the inhomogeneity region and then to finding the desired field of sound velocities in this region. The algorithm solves the inverse problem on a typical personal computer for sufficiently fine three-dimensional grids in a few minutes without parallelization. A numerical study of the accuracy of the proposed algorithm and its stability with respect to data perturbations is carried out for model inverse problems at one frequency and simultaneously at several frequencies.

A.S. Fomochkina, B.G. Bukchin

Identification of the fault plane in the inverse problem of determining the source of earthquakes

One of the key characteristics of an earthquake is its focal mechanism, which determines two orthogonal nodal planes. One nodal plane is the fault plane and the other is orthogonal to the slip vector. When the source of the earthquake is described by the double-couple point source model (a slip on a plane), these two planes are indistinguishable based on the seismological data. When the finite dimensions of the source area are taken into account, fault plane identification becomes in principle possible. The possibility of identifying the fault plane based on analysis of stress glut second moments.

A. V. Lapin

Numerical solution of a time-fractional one-phase Stefan problem

We consider a time-fractional one-phase Stefan melting problem which involves a memory of the latent-heat accumulation. Using the enthalpy function, the problem is formulated as a parabolic variational inequality. It is approximated by an implicit finite difference scheme. Estimates of the velocity of the moving boundary (phase transition boundary) are given. They provide us knowledge about the "narrow" strip of location of this boundary. Thus, we must solve the nonlinear problem at the points of this strip and the linear equation in the rest, a larger domain. Various domain decomposition methods can be used to implement the constructed mesh problem using this information.

N.Y. Chernikova

A numerical optimization method in the problem of comparing the spatial structure of molecules in a crystal

The geometric difference in the relative arrangement of atoms in molecules with the same chemical formula significantly affects the properties of the crystal. For quantitative comparison of the spatial geometric structure of two molecules, we used the method of optimal superposition of molecules through the minimization of a certain comparison function by rotating the molecules after superposing their centers of mass. The search for the minimum of the comparison function over Euler rotation angles is performed by the Rosenbrock method. The assumed criterion for comparing molecules allows us to quantify the proximity in the spatial structure of molecules. The implementation of the method is shown by comparing the structure of eight molecules in four crystalline substances.

P. Stognii

The influence of the methane bombs on the process of hydrocarbon deposits detection

In this work, the influence of the methane bombs on the process of hydrocarbon deposits detection is investigated. The analysis of the models with and without hydrocarbon deposits, the models with extra geological layers, computed by the grid-characteristic method, demonstrate the possibility of distinguishing the seismic reflections from the hydrocarbon deposits from the other seismic noise.

V. Golubev, A. Borisova, V. Petrukhin, A. Shevchenko

The simulation of anisotropic elastic media with the grid-characteristic method

Nowadays, seismic survey is the common method for the hydrocarbon exploration. Based on the analysis of reflected waves, registered at the day surface, an internal structure of oil and gas deposits can be discovered. With the development of modern high-performance computing systems, more complicated physical models are used for describing the dynamic behavior of geological media. One of the interesting geological objects is the fractured layer. It is often connected with the oil-bearing formation. Individual cracks may be a simple oil storage or a fluid conducting path. That is why the identification of fractured horizons based on the field seismic data is an important question. The presence of cracks inside the medium leads to the anisotropy of the seismic signal. The analysis of it may be used to identify the preferred direction of fractures. In this work the grid-characteristic method was extended to the anisotropic linear-elastic case in two dimensions. Wave patterns and synthetic seismograms were successfully simulated. The reported study was funded by RFBR, project number 20-01-00261.

F. Sergeev, I. Petrov, M. Muratov

Computer simulation of dynamic processes in industrial ice structures

Artificial islands have long been used for offshore gas and oil production. In the Arctic, it is effective to construct them out of ice, as it is an accessible, cheap and environmentally friendly building material. The drawback of using ice is its tendency to crack even under small static loads. Cracks compromise the integral stability of the island and present a safety hazard to staff [1]. Artificial ice islands can also be/are used as temporary facilities for seismic exploration, melting down on their own during the warm season. Elastic waves from drilling and seismic activity interfere with the exploration impulse response and present a challenge to model and account for. In this work, we consider a two-dimensional numerical simulation of propagation of elastic waves in an ice island during drilling, seismic exploration and seismic activity, as well as perform stress analysis of the island. We use the grid-characteristic method on regular rectangular meshes, since it allows to set correct boundary and contact conditions [2], [3]. [1] I.B. Petrov, "Problems of simulation of natural and anthropogenous processes in the Arctic zone of the Russian Federation", Matem. Mod., 30:7 (2018), 103–136. [2] A.V. Favorskaya, I.B. Petrov, D.I. Petrov, N.I. Khokhlov, "Numerical modeling of wave processes in layered media in the Arctic", Matem. Mod., 27:11 (2015), 63–75; Math. Models Comput. Simul., 8:4 (2016), 348–357. [3] A.S. Kholodov, Ya.A. Kholodov, "Monotonicity criteria for difference schemes designed for hyperbolic equations", Zh. Vychisl. Mat. Mat. Fiz., 46:9 (2006), 1638–1667; Comput. Math. Math. Phys., 46:9 (2006), 1560–1588.

M.V. Muratov, D. Konov, V. Biryukov

The solution of Stefan problem for seasonal phase changes of ice islands

Active development of Arctic makes construction of shelf infrastructure objects for production and searching for crude oil and gas deposits a priority. It is appropriate to use artificial ice islands, because they are economical and could be built quickly. Crucial task is to ensure its resistance to melting during operation in spring and summer period. This work presents an approach to numerically model three-dimensional ice melting problem with enthalpy method. Phase transition is modeled considering heterogeneous thermophysical properties of ice, which could appear due to surface freezing features, environment temperature variation, solar activity throughout calendar year. This particular approach may be used to optimize the shape and size of the island, to study feasibility of introducing thermal insulation layers and freezing technology variation according to certain climate conditions. For ice foundation interaction with surrounding ice field and water, temperature on the boundary between island and ice field is intended to be used. Similar approach is intended to be utilized for underlying soil interaction modelling – nearest region is explicitly present in the calculation while the rest of the volume is modelled with boundary condition (equivalent values or symmetry – according to parameter availability). Problem, which describes the change of phase of matter and phase boundary movement, is called Stefan problem. There are several approaches to solving this task. In this study enthalpy method was chosen, its description can be found in works [1-2]. The main reason behind this choice is an ability to effectively implement the solution of this task in form of software package. Temperature of surrounding water is to be set explicitly in this model. Water movement (tidal currents) is not modeled explicitly in this calculation, but their influence is considered through boundary conditions and direct setting of temperature. Heterogeneity of ice and soil is taken into account with use of separate layers in the structure and the parameters for each layer are set independently and are explicitly considered in the calculation. Dependence of ice properties on building conditions, freezing mode and ice constitution are considered with use of effective characteristics for each considered layer. It is intended that model will have options to change the following parameters: • Geometry of ice foundation (diameter, overall height, height of surface part) • Geometry and physical properties of soil, ice and air (density, thermal conductivity, specific heat capacity, specific heat of fusion) • Structure of ice foundation (homogeneous or laminate, individual layer media properties) • Heat flux from external sources(equipment) • Solar activity magnitude throughout year or day References 1. R.E. White. An enthalpy formulation of the Stephan problem // SIAM J. Numer. Anal., Vol. 19, No. 6, December 1982, pp. 1129-1157 2. R.E. White. A numerical solution of the enthalpy formulation of the Stephan problem // SIAM J. Numer. Anal., Vol. 19, No. 6, December 1982, pp. 1158-1172

M.V. Muratov, I.B. Petrov

Exploration seismology inverse problems solution by methods of machine learning

Recent years, machine learning techniques and, in particular, deep neural networks have shown impressive results in many areas, such as computer vision, speech recognition and machine translation. For example, in the field of computer vision, it was possible to solve many problems previously unsolved, such as the classification problem [1], the recognition problem [2], and the problem of image generation [3]. One of the significant advantages of deep learning methods is that these methods can be transferred to many other areas related to processing of large amounts of data. One such area is the exploration seismology problems. Several works in this field have already been carried out. In [4], the problem of fault detection in 2D was solved using a deep convolutional neural network. As data for training the neural network, we used synthetic data obtained by solving large direct problems. In [5], a similar problem was solved in 3 dimensions. The great advantage that these papers draw attention to the input data for deep learning algorithms, which do not require special processing and, therefore, such methods can be simpler to use than standard exploration seismology methods. Flexibility and relative simplicity make such methods effective for solving practical problems. So, in [6], deep neural networks are used to detect CO2 emissions, and in [7], these methods are used to detect and classify defects in composite materials. The results show that the use of machine learning methods in exploration seismology is important topic for research. The research was supported by RFBR, grant No. 20-01-00572 A References: 1. Krizhevsky A., Sustskever I., Hinton G.E. Imagenet classification with deep convolutional neural networks // Advances in neural information processing systems. – 2012. – P. 1097-1105. – DOI: 10.1145/3065386. 2. Szegedy C., Toshev A., Erhan D. Deep neural networks for object detection // Proceeding NIPS'13 Proceedings of the 26th International Conference on Neural Information Processing Systems. – 2013, Vol. 2. – P. 2553-2561. 3. Goodfellow I., Pouget-Abadie J., Mirza M., Xu B., Warde-Farley D., Ozair S., Courville A., Bengio Y. Generative adversarial nets // Advances in neural information processing systems. – 2014. – P. 2672-2680. 4. Zhang C., Frogner C., Araya-Polo M., Hohl D. Machine-learning Based Automated Fault Detection in Seismic Traces // EAGE Conference and Exhibition 2014. – DOI: 10.1190/tle36030208.1. 5. Araya-Polo M., Dahlke T., Frogner C., Zhang C., Poggio T., Hohl D. Automated fault detection without seismic processing // The leading eadge. – 2017, Vol. 36, Iss. 3. – P. 194-280. – DOI: 10.1190/tle36030208.1 6. Wu Yu., Lin Yo., Zhou Zh., Delorey A. Seismic-Net: A Deep Densely Connected Neural Network to Detect Seismic Events // CoRR. – 2018, abs/1802.02241. 7. Menga M., Chua Y.J., Woutersonb E., Ong C.P.K. Ultrasonic signal classification and imaging system for composite materials via deep convolutional neural networks // Neurocomputing. – 2017, Vol. 257. – P. 128-135. – DOI: 10.1016/j.neucom.2016.11.066.

M.Muratov, V. Ryazanov

Inverse problems of fractured layers exploration seismology solution with use of convolutional neural networks

This report is devoted to solving the inverse problems of exploration seismology of uniformly oriented macrofractures systems using convolutional neural networks. The use of convolutional neural networks is optimal due to the multidimensionality of the studied data object. A training sample was formed using mathematical modeling. In the numerical solution of direct problems, a grid-characteristic method with interpolation on unstructured triangular meshes was used to form a training sample. The grid-characteristic method most accurately describes the dynamic processes in exploration seismology problems, since it takes into account the nature of wave phenomena. The approach used makes it possible to construct correct computational algorithms at the boundaries and contact boundaries of the integrational domain. Fractures were set discretely in the integration domain in the form of boundaries and contact boundaries. The article presents the results of solving inverse problems with variations in the angle of inclination of fractures, height of fractures, density of fractures in the system, as well as joint variations in the angle of inclination and height of fractures and all three investigated parameters.

E. Pesnya, A. Kozhemyachenko, A. Favorskaya

Implicit methods in modeling of linear-elastic body

Implicit method is applied to study the propagation of mechanical stresses in the model of a linear-elastic isotropic body. This work has been performed with the financial support of the Russian Science Foundation (project No. 20-71-10028).

A.I. Lopato, Ya. Poroshyna, P.S. Utkin

Numerical simulation of shock wave propagation in the non-uniform media in the shock-attached frame

The study of the dynamics of shock and detonation wave propagation in a medium characterized by non-uniform distribution of parameters is an actual problem in the context of detonation engines development. Due to the unsteadiness of the processes, the separate supply of the fuel and oxidizer the conditions in the combustion chamber are far from uniform. It was found that the known algorithms for the simulation of shock and detonation wave in the shock-attached frame (SAF) may be unstable in the case of non-uniform distribution of parameters in front of the leading shock. The relatively rough test case was considered - Shu problem about an inert SW propagation in a medium with non-uniform distribution of density. We propose new implicit numerical algorithm for the robust simulation of the shock wave propagation in the SAF.

M. Seleznov, A. Vasyukov

Solving problems of the strength of a thin thread by machine learning methods

The talk considers the construction of a surrogate machine learning model for the problem of deformation and breakage of a thin thread under the action of a transverse load. This dynamic physical problem is computationally simple, which makes it convenient for testing various approaches, but at the same time it contains a significant range of effects, which allows us to expect that the methods worked out on it can be further applied to more complex problems. The talk discusses an algorithm for the formation of a small training set, which will still provide a reasonable quality of the surrogate model. It was found that machine learning model can provide a reasonable quality of prediction for a dynamic physical problem even with a small training set - an F-score of above 0.8 is obtained when training on 500 samples. Quantitative characteristics for other tasks can vary significantly; some issues regarding it are also discussed in the talk. The reported study was funded by RFBR, project number 18-29-17027.

M.S. Stankevich

Using convolutional neural networks for inverse problems of boundary location in heterogeneous medium

The problem of locating the boundary between two heterogeneous substances is considered. The problem statement implies having only partial information about the physical properties of the medium. The method obtains information about the structure of the medium from elastic wave propagation and reflection. Solving inverse problems is based on convolutional neural networks, which achieved good results on ill-posed image segmentation problems in recent years. The method proposed is based on the assumptions that the continuous observations of wave amplitude and velocity on the surface of the medium could also be treated as images, and the initial problem can be reduced to the optimization problem. The numerical modeling approach is used to create datasets of sufficient size: wave propagation through the medium is simulated numerically using discontinuous Galerkin method. The reported study was funded by RFBR, project number 18-29-02127.

N. Tupitsa, P. Dvurechensky, A. Gasnikov, C. Uribe

Multimarginal optimal transport by accelerated alternating minimization

We consider a multimarginal optimal transport, which includes as a particular case the Wasserstein barycenter problem. In this problem one has to find an optimal coupling between mm probability measures, which amounts to finding a tensor of the order mm. We propose an accelerated method based on accelerated alternating minimization and estimate its complexity to find the approximate solution to the problem. We use entropic regularization with sufficiently small regularization parameter and apply accelerated alternating minimization to the dual problem. A novel primal-dual analysis is used to reconstruct the approximately optimal coupling tensor. Our algorithm exhibits a better computational complexity than the state-of-the-art methods for some regimes of the problem parameters.

P. Dvurechensky, A. Gasnikov, A. Kroshnin
On the complexity of optimal transport problems
We consider the problem of computational complexity of optimal transport distances. Alternating minimization algorithm (Sinkhorn's algoruthm) and accelerated gradient descent method are considered in this context. Joint work with A. Gasnikov, A. Kroshnin

E.L. Gladin
Approaches to solving convex-concave saddle point problems
Fast gradient method, accelerated gradient sliding and other algorithms are employed to solve min-max problems. The approaches have linear rate of convergence.

A.V. Gasnikov
Accelerated local SGD
We propose new accelerated version of popular local SGD procedure.

M.V. Klibanov
Carleman estimates for globally convergent numerical methods for coefficient inverse problems
A Coefficient Inverse Problem (CIP) is a problem of finding an unknown coefficient of a Partial Differential Equation (PDE) from boundary measurements of the solution of this PDE. That coefficient describes a physical property of an unknown medium, e.g. acoustic speed, dielectric constant, electric conductivity, heat conduction, etc. The latter clearly indicates a large volume of applications of CIPs. However, there is a fundamental challenge in the goal of the numerical solution of any CIP. Indeed, any CIP is both nonlinear and ill-posed. These two factors cause the well known phenomenon of multiple local minima and ravines of any conventional Tikhonov least squares functional. Since, on the other hand, any gradient-like method of the minimization of this functional stops at any point of a local minimum, which is not necessary close to the correct solution, then conventional optimization methods deliver unstable and unreliable solutions for CIPs. To overcome the above stumbling block, we have invented a radically new numerical method, called "convexification". The convexification constructs globally strictly convex Tikhonov-like functionals for CIPs. The key point of such a functional is the presence of the so-called Carleman Weight Function. This is the function which is involved in the so-called Carleman estimate for the original

PDE operator. The global strict convexity guarantees all nice properties which numerics wants: 1. The absence of local minima of that new functional. 2. The existence of the unique global minimum. 3. The global convergence to the correct solution of the gradient projection method of the optimization of that functional. 4. A good first guess for the solution is no longer necessary. The convexification is a universal approach which works for a broad variety of CIP. First, we will present the theory of the convexification for just one example of a CIP for the Helmholtz equation in 3D. Next, we will present numerical results for this CIP. In particular, we will present results for microwave experimental data. The data were collected in our microwave laboratory. Next, we will give an overview of all other convexification-like results for many CIPs which we have obtained so far.

A.A. Shananin

The Yang`s duality and its application to the aggregation of the balances

V. V. Leontiev's method of intersectoral balance was awarded the Nobel prize in Economics and was successfully used in the XX century to analyze extensive recovery growth of the economy. Models of intersectoral balance allowed us to build multipliers, identify bottlenecks in economic dynamics, and determine the drivers of economic growth. The method of V. V. Leontiev was based on the system of material balance and the hypothesis of the constancy of the norms of production costs in the process of intersectoral interaction. However, in the 1990s, the nature of economic dynamics in developed capitalist countries changed: the extensive increase in production volumes was replaced by an increase in the variety and quality of goods and services. Under these conditions, V. V. Leontiev's hypothesis about the constancy of cost rates no longer corresponds to the increased interchangeability of goods and services. Using the Yang transform and the Fennel duality theorem, the paper proposes an operation generalizing convolution, and constructs an aggregation model of an intersectoral balance with concave positively homogeneous production functions. Using the Yang transform and the Fenchel duality theorem, the paper proposes an operation generalizing convolution, and constructs an aggregation model of an intersectoral balance with concave positively homogeneous production functions.

L. Baratchart, D. Hardin, C. Villalobos-Guillén

Inverse potential problems in divergence form and divergence free measures in the plane

We consider the problem of recovering a measure supported in a plane, knowing a(component of) the field of the potential of its divergence on a portion of plane away from the the support. We show that a regularization scheme that penalizes the total variation is consistent when the support of the measure is purely 1-unrectifiable, and that the regularized criterion has a unique minimum. To this effect, we establish a loop decomposition of divergence-free measures in the plane.

H. Haddar, F. Cakoni, D. Colton

Duality between scattering poles and interior transmission problems

We develop a conceptually unified approach for characterizing and determining scattering poles and interior eigenvalues for a given scattering problem. Our approach explores a duality stemming from interchanging the roles of incident and scattered fields in our analysis. Both sets are related to the kernel of the relative scattering operator mapping incident fields to scattered fields, corresponding to the exterior scattering problem for the interior eigenvalues, and the interior scattering problem for scattering poles. Our discussion includes the scattering problem for a Dirichlet obstacle where duality is between scattering poles and Dirichlet eigenvalues, and the inhomogeneous scattering problem where the duality is between scattering poles and transmission eigenvalues. Our new characterization of the scattering poles suggests a numerical method for their computation in terms of scattering data for the corresponding interior scattering problem.

R.A. Chertovskih, V.A. Zheligovsky

Does the alpha-effect exist?

The role of alpha-effects in nature is questioned on the basis of numerical analysis of Bloch eigenmodes of the magnetic induction operator.

M.I. Belishev

Electric impedance tomography problem for nonorientable surfaces

The 1d Dirac dynamical system Σ is $iu_t + Ju_x + Vu = 0, x,, t > 0; u|_{t=0} = 0, x \geq 0; u_1|_{x=0} = f, t \geq 0,$ where $J = (0 \quad 1 - 1 \quad 0); V = \begin{pmatrix} p & q \\ q & -p \end{pmatrix}$ with real $p, q;$ $u = \begin{pmatrix} u_1^f(x,t) \\ u_2^f(x,t) \end{pmatrix}$ is the trajectory in $\mathcal{H} = L_2(\mathbb{R}_+; \mathbb{C}^2); f \in \mathcal{F} = L_2([0,\infty); \mathbb{C})$ the boundary control. System Σ is not controllable: the total reachable set $\mathcal{U} = \mathrm{span}_{t>0}\{\mathrm{u}^{\mathrm{f}}(\cdot,\mathrm{t})|\mathrm{f} \in \mathcal{F}\}$ is not dense in $\mathcal{H}$, but contains a controllable part Σ_u . We construct a dynamical system Σ_a, which is controllable in $L_2(\mathbb{R}_+; \mathbb{C})$ and connected with Σ_u via a unitary transform. The construction is based on geometrical optics relations: trajectories of Σ_a are composed of jump amplitudes that arise as a result of projecting in $\overline{\mathcal{U}}$ onto the reachable sets $\{\mathrm{u}^{\mathrm{f}}(\cdot,\mathrm{t})|\mathrm{f} \in \mathcal{F}\}$. System Σ_a, which we call the *amplitude model* of the original Σ, has the same input/output correspondence as system Σ. As such, Σ_a provides a canonical completely reachable realization of the Dirac system.

E.L. Korotyaev

Inverse spectral theory for perturbed torus

We consider an inverse problem for Laplacians on rotationally symmetric manifolds, which are finite for the transversal direction and periodic with respect to the axis of the manifold, i.e., Laplacians on tori. We construct an infinite dimensional analytic isomorphism between the space of profiles (the radius of the rotation) of the torus and the spectral data as well as the stability estimates: those for the spectral data in terms of the profile and conversely, for the profile in term of the spectral data. Jointly with Hiroshi Isozaki, Japan.

A. Jollivet

On a first variation formula for the Steklov zeta function of a smooth planar domain

We address the question of reconstructing a bounded smooth and simply connected planar domain Ω from the spectrum of its Dirichlet-to-Neumann operator (Steklov spectrum). We state analog formulations of this problem, one of them arising from Electrical Impedance Tomography. We introduce a first variation formula for the Steklov spectral zeta function ζ_Ω when one smoothly deformes the domain Ω (with 2π perimeter). We prove that $\zeta_\Omega \geq \zeta_{\mathbb{D}}$ on $R\backslash\{1\}$ by choosing an appropriate path of deformation where $\mathbb{D}$ is the unit disk. These results generalize a result in [1] on the derivative $\zeta'_\Omega(0)$ and our previous work [3]. We also discuss application of the first variation formula to the question of nonexistence of nontrivial isospectral deformations of a planar domain. This talk is based on joint works [2,3,4,5] with Vladimir Sharafutdinov (Novosibirsk State University & Sobolev Institute of Mathematics). References 1. J. Edward and S. Wu, Determinant of the Neumann operator on smooth Jordan curves, Proc. Amer. Math. Soc. 111(2), 357--363 (1991). 2. A. Jollivet and V. Sharafutdinov, On an inverse problem for the Steklov spectrum of a Riemannian surface. Inverse problems and applications, Eds. P. Stefanov, A. Vasy, M. Zworski, Contemporary Mathematics 615, 165--191 (2014). 3. A. Jollivet and V. Sharafutdinov, An inequality for the zeta function of a planar domain, J. of Spectral Theory, J. Spectr. Theory 8(1), 271--296 (2018). 4. A. Jollivet and V. Sharafutdinov, Steklov zeta-invariants and a compactness theorem for isospectral families of planar domains, J. Funct. Anal. 275(7), 1712--1755 (2018). 5. A. Jollivet and V. Sharafutdinov, An estimate for the Steklov zeta function of a planar domain derived from a first variation formula, preprint 2020.

K.B. Sabitov

Inverse problems for the equation of oscillations of a rectangular plate to find the source

In this work, we study a problem with initial conditions for the equation of oscillation of a plate pivotally fixed at the edges. The energy inequality is established, from which the uniqueness of the solution of the stated initial-boundary problem follows. Based on the solution of this problem, the inverse problems of finding an external source of oscillations are posed and investigated. The uniqueness and existence theorems of solutions to the problems are proved. Moreover, the solutions themselves are constructed in an explicit form - in the form of a sum of orthogonal series.

M. Ismailov

Borg - type uniqueness theorem for first - order hyperbolic system on half-axis

The first order hyperbolic system on the half-axis in the case of equal number of incidend and scattered waves is considered. In general, it is observed that one scattering problem is not enough for unique restoration of the potential when the number of equations of the hyperbolic system is more than two equations. It is determined two scattering problems for the same hyperbolic system but two different boundary conditions for ensuring the unique recovering the potential from the scattering operators. The inverse scattering problem is studied by utilizing linear integral equations of the Gelfand–Levitan–Marchenko type.

M.M. Malamud

Inverse spectral problems for first order systems of ordinary differential equations

Inverse spectral problems for selfadjoint boundary value problems generated by first order systems on finite or infinite intervals will be discussed. Construction of potential matrices with prescribed singular spectrum will be discussed too.

A. Badanin

Hill's equations with the potentials analytically dependent on energy

We consider Hill's equations on the line with potentials that are periodic with respect to the coordinate variable and real analytic with respect to the energy variable. We prove that if the imaginary part of the potential is bounded in the right half-plane, then the high energy spectrum is real, and the corresponding asymptotics are determined. Moreover, the Dirichlet and Neumann problems are considered. The results are used to analyze the good Boussinesq equation.

N. Saburova

Trace formulas for Laplacians on periodic discrete graphs

We consider Laplace operators on periodic discrete graphs. It is known that the spectrum of the operators consists of a finite number of bands. We obtain trace formulas for the Laplacians. The traces are expressed in terms of geometric parameters of the graph: vertex degrees, cycle indices, numbers of cycles. As an application of the trace formulas we obtain some estimates for the spectrum of the Laplacian. The proof is based on the decomposition of the Laplacian into a direct integral and a precise expression of fiber operators. This is a joint work with Korotyaev E.L. from St. Petersburg State University.

A.V. Arutunov, S.E.Zhukovskiy

On variational principles in nonlinear analysis

In the talk, there will be presented some generalizations of the known variational principles of nonlinear analysis. The relation between known principles and their generalizations will be discussed. The will be considered some applications of these results to the problem of nonlinear equations solvability.

V.S. Dryuma

On the Ricci-flat metric in the theory of Navier-Sokes equations and its applications

To construct solutions of the Navier-Stokes system of equations and study its properties, we use the 14-dimensional partially-projective Riemannian space equipped with a Ricci-flat metric on solutions of the system. The introduced metric belongs to the class of metrics with Cartan invariants of generalized Riemannian spaces, in terms of which possible reductions of the Navier-Stokes equations are studied and examples of their solutions are constructed.

L.V. Bogdanov

Matrix extensions of dispersionless integrable systems and Bogomolny equations on an Einstein-Weyl geometry background

We derive a (2+1)-dimensional Toda type dispersionless integrable system describing a general local form of three-dimensional Einstein-Weyl geometry with positive (Euclidean) signature, construct its matrix extension and demonstrate that it represents Bogomolny equations for non-abelian monopole on an Einstein-Weyl geometry background. The corresponding integrable hierarchy and a dressing scheme are also considered.

M. Pavlov

Multi-dimensional integrable Lagrangian systems

In this talk we consider integrability of multi-dimensional quasilinear systems of first order, determined by the Lagrangian densities, depended on second derivatives of a single unknown function only

A.S. Mikhaylov, V.S. Mikhaylov (PDMI RAS, Russia)

Toda lattice for semi-bounded initial data and classical moment problem

We define the solution of semi-infinite Toda lattice for wide class of unbounded initial data. By using some ideas of Moser for finite-dimensional case, we derive the evolution of moments of spectral measure of Jacobi operator associated with Toda lattice via the Lax pair.

A.S. Demidov

On numerically realizable explicit formulas for solutions of 2- and 3-dimensional equations $div(\alpha\nabla\omega) = 0, div(\beta(\omega)\nabla\omega) = 0$ with Cauchy analytic data on the analytic boundary.

Explicit formulas serve as a control test of numerical algorithms for finding solutions of ill-posed problems. As examples of such ill-posed problems one may consider inverse problems of equilibrium plasma in tokamaks and the inverse problem of electromagnetic encephalography. The talk contains a construction of numerically realizable explicit formulas for the solutions of 2D or 3D elliptic equations with analytic Cauchy data on an analytic curve or surface

A.Faminskii

On inverse problems with integral overdetermination for the Korteweg-de Vries equation

Для уравнения Кортевега-де-Фриза рассматриваются начальные и начально-краевые задачи, поставленные как на ограниченном, так и на неограниченном интервалах $I\ u_t + bu_x + u_{xx} = f(t,x)$ в ситуации, когда либо одно из граничных условий, либо правосторонняя функция f неизвестны. Вместо этих данных специальное дополнительное интегральное условие вида $\int_{I u}(t,x)\omega(x)dx = \varphi(t)$ для заданных функций ω и φ предполагается. Результаты об уникальной разрешимости таких обратных задач устанавливаются либо для малых входных данных, либо для малого временного интервала.

A.B. Ryabtsev

The error accumulation in the conjugate gradient method for degenerate problem

In this paper, we consider the method of conjugate gradients in solving the problem of minimizing a quadratic function with additive noise in the gradient. Three concepts of noise were considered: antagonistic noise in the vector, stochastic noise in the vector and noise in the matrix, as well as combinations of the first and second with noise in the matrix. It was experimentally obtained that error accumulation is absent for any of the considered concepts, which differs from the assumption of many experts who believe that, as in accelerated methods, there is error accumulation. The paper gives a motivation for why the error may not accumulate. The dependence of the solution error both on the noise value and on the size of the solution was also experimentally investigated using the conjugate gradient method. The hypotheses about the solution error for all the concepts considered were tested: linearity in the magnitude of the noise and the size of the solution - for the noise in the vector, as well as linearity in the magnitude of the noise and the squareness of the dependence on the size of the solution - for the noise in the matrix. The work contains graphs illustrating each individual study, as well as a detailed description of numerical experiments, which includes an account of the methods of noise both vector and matrix.

E. Gorbunov, D. Kovalev, P. Richtárik

Towards new distributed methods with error feedback and delayed updates

In this talk, we will discuss several popular approaches in parallel distributed optimization aimed at the reduction of communication time. I will show that one can analyze all these methods in a unified way that shows the weaknesses and strengths of the existing approaches and offers to develop new distributed methods with provably better convergence rates. Finally, to illustrate the generality of the proposed analysis I will demonstrate how the proposed framework can be used to obtain new methods with delayed updates.

F.S. Stonyakin

Non-smooth convex programming problems: inexactness and relative accuracy

We propose several adaptive algorithmic methods for problems of non-smooth convex optimization. Analogues of switching subgradient schemes are proposed for inexact subgradients. Moreover, we investigate some classes of non-Lipshitz objective functionals with inexact data. We obtain estimates for the quality of the solution with relative accuracy for the problem of minimizing a homogeneous convex functional using fairly general assumptions.

A. Sadiev, A. Beznosikov, A. Gasnikov

Gradient-free methods with inexact oracle for convex-concave stochastic saddle-point problem

In the paper, we generalize the approach Gasnikov et. al, 2017 that allows solving (stochastic) convex optimization problems with inexact gradient-free oracle to convex-concave saddle-point problem. The proposed approach works at least like the best existing approaches. But for special set-up (simplex type constraints and closeness of Lipschitzconstants in 1 and 2 norms) our approach reduces n/log(n) times the required number of oracle calls (function calculations).