LABORATORY OF NUMERICAL METHODS OF APPLIED STRUCTURAL OPTIMIZATION
Mission & Goals

Mission
- Solving hard practical optimization problems
- State-of-the-art research in optimization theory and methods

Goals
- Find elegant and simple solutions for complex actual problems
- Create optimization method's frameworks
- Extend the domain of optimization theory applicability
- Develop new numerical optimization methods and improve existing ones
- Investigate optimization methods properties and effectiveness
Team. Lead Researchers

Acad. Dr. Yury Evtushenko
Chief Researcher - Head of the laboratory

Dr. Mikhail Posypkin
Lead Researcher

Dr. Vladimir Zubov
Lead Researcher

Dr. Alexandr Gasnikov
Lead Researcher

Dr. Vitalii Zhadan
Lead Researcher

Phd. Alexey Chernov
Senior Researcher - Deputy Head

Phd. Andrey Gorchakov
Senior Researcher

Phd. Alexandr Biryukov
Senior Researcher

Phd. Fedor Stonyakin
Senior Researcher

Marina Danilova
Junior Researcher

Dmitrii Kamzolov
Junior Researcher

Daniil Merkulov
Junior Researcher

01.09.2018

Laboratory NuMASO
Academic Degrees:
- 2006 Academician of the Russian Academy of Sciences
- 1985 Professor
- 1981 Doctor of Physical and Mathematical Sciences, Computing Centre of the USSR Academy of Sciences (CCAS)

Research Interests:
- Linear and Nonlinear Programming
- Decision Support Systems
- Optimal Control
- Optimization Techniques
- Numerical Methods and Software for Solving Global Multicriteria Optimization

Professional Experience:
- 1989 - p.t. Director of Dorodnicyn Computing Centre of RAS
- 1981 - 1989 Deputy Director of Dorodnicyn Computing Centre
- 1978 - 1981 Head of Subdepartment in the Department of operation research, CCAS
- 1973 - 1978 Senior Researcher, CCAS
- 1967 - 1972 Junior Researcher, Computing Centre of the USSR Academy of Sciences (CCAS)
- 1966 - 1967 Junior Researcher, Central Aerohydrodynamic Institute (TsAGI)
- 1965 - 1966 Senior engineer (TsAGI)
- 1962 - 1965 Post graduate student at Moscow Institute of Physics and Technology
Research Directions

- Structural optimization
- Numerical methods of local and global optimization theory
- Multicriteria optimization
- Nonconvex and non-smooth optimization
- Linear and nonlinear programming, semidefinite and equilibrium programming
- Numerical methods of optimal control
- Stochastic optimization
- High-performance techniques in optimization
- Distributed optimization
Competencies

- Machine Learning
- Traffic assignment problems
- Computer networks modeling
- Inverse problems of mathematical physics
- Optimal Control in the Foundry Industry
- Global Optimization
- Robotics: Approximation of the Robot’s workspace
- Fast Automatic Differentiation
- Non-linear analysis and its applications
- Software Framework
- Software Development
Machine Learning

- PageRank problem solution (nonconvex optimization) Cooperation with
  - CORE UCL (Yu. Nesterov)
  - Yandex

- Distributed optimization with sum-type target functions Cooperation with A. Nedic

- Image analysis (Monge-Kantorovich-Wasserstein transport distance) Cooperation with WIAS Berlin (P. Dvurechensky, V. Spokoiny)
Traffic assignment problems

- **Applications**
  - Cars transport
  - Railways

- **Short-term modeling and Long-term modeling: traffic assignment problems, mechanism design (road pricing)**
  - How to predict the situation on the roads for an hour ahead?
  - How to road price to achieve a system optimum?
  - Where is it necessary to make reverse strips and dedicated lanes for public transport?
  - How to optimally manage traffic signaling and access to major highways?
  - How to optimally manage traffic flows?

- **Publics:**
Computer networks modeling & inverse problems of mathematical physics

Inverse problems of mathematical physics
Cooperation with A. Kabanikhin (Novosibirsk)

Modeling of computer networks (Large scale and huge scale optimization)
Cooperation with Huawei
Control of the process of crystallization of metal in the foundry industry

Optimal control for foundry form

\[ u(t) \] is the velocity of the foundry form
Determination of the thermal conductivity of a substance by the dynamics of the temperature field


"Recovery" of the function K (T) over a given temperature field with machine quality (accuracy)

\[ \Phi_{ini} = 3.0196 \cdot 10^{-2} \quad \Phi_{opt} = 2.9909 \cdot 10^{-26} \]
Global Optimization

Overview

- A deterministic global optimization method
- Allows to approximate function extrema, sets given by the system of equations, inequalities or mapping with the pre-defined precision
- Method was successfully parallelized for multicore systems with shared and distributed memory organization

Publications

Robotics: Approximation of the Robot’s workspace

DexTAR parallel robot

Workspace
Robotics: Approximation of the Robot’s workspace

- The scientific reserve in the field of modeling of robots of parallel structure is created.
- Methods for approximating the working area of the robot and the corresponding software have been developed.
- Approaches have been developed for solving robot control problems, based on the methodology of rapid automatic differentiation of objective functions and task constraints.
Fast Automatic Differentiation

4D-Var data assimilations

Initial conditions search

spherical wave

FAD technique: development of high-performance packages
Non-linear analysis and its applications

- Applications of non-linear analysis in extremal problems (analogues of Fermat-Torricelli-Shteiner problem)

- Universal and adaptive methods for variation inequities and saddle problems. Equilibrium search problems
  https://arxiv.org/abs/1806.05140

- Optimization of functional with non-standard growth conditions, incl. arising when solving problems Truss Topology Design.
  https://arxiv.org/abs/1710.06612
  https://arxiv.org/abs/1803.01329
Software framework

- NUMERIC UTILITIES
- INTERVAL ARITHMETICS LIBRARY
- EXPRESSIONS LIBRARY

NON-UNIFORM COVERING METHOD "LOGIC"

- SEQUENTIAL
- GPU (CUDA)
- SHARED MEMORY
- DISTRIBUTED (BOINC)
- DISTRIBUTED MEMORY
Software framework: Expressions library

- Allows to declare complex formulas

- Supports automated evaluation of a function value, its derivatives, interval bounds and interval bounds for derivatives

```cpp
template <class T> Expr<T> Rosenbrock(int n) {
    Expr<T> x;
    Iterator i(0, n-2);
    Expr<T> t = i;
    return loopSum(100*sqr(x[t+1]-sqr(x[i]))+sqr((x[i]-1)), i);
}
```
Software Development

- **Project Development**
  - Starting the project
  - Organizing and Preparing
  - Carrying out the project work
  - Closing the project

- **Life cycles**
  - Iterative and incremental
  - Waterfall

![Iterative and incremental diagram]

![Waterfall diagram]
Software Development

- Project Documentation
  - Atlassian Confluence
  - Atlassian JIRA
  - Trello
  - Visio
  - Enterprise Architect
  - Unified Modeling Language (UML)
  - BPMN
  - SharePoint

- Version control systems
  - git
  - CVS
  - TortoiseSVN
  - Subversion
Software Development

- Hadoop Technology stack
  - hadoop
  - MapReduce
  - Apache ZooKeeper™
  - Hadoop
  - Spark
  - HIVE
  - Apache Camel

- Programming Languages & Frameworks
  - Java
  - ORACLE
  - C#
  - Python
  - BASH
  - MATLAB
  - NVIDIA CUDA

- Databases
  - ORACLE
  - Microsoft SQL Server
  - PostgreSQL
  - MySQL

- Platforms
  - Windows
  - Linux

- IDEs
  - jupyter
  - Apache Zeppelin
  - IJ
  - PC
  - eclipse
  - Visual Studio
  - PL/SQL Developer
  - Oracle SQL Developer