

# Communications in Computer and Information Science


1129

*Commenced Publication in 2007*

Founding and Former Series Editors:

Phoebe Chen, Alfredo Cuzzocrea, Xiaoyong Du, Orhun Kara, Ting Liu,  
Krishna M. Sivalingam, Dominik Ślęzak, Takashi Washio, Xiaokang Yang,  
and Junsong Yuan

## Editorial Board Members

Simone Diniz Junqueira Barbosa 

*Pontifical Catholic University of Rio de Janeiro (PUC-Rio),  
Rio de Janeiro, Brazil*

Joaquim Filipe 

*Polytechnic Institute of Setúbal, Setúbal, Portugal*

Ashish Ghosh

*Indian Statistical Institute, Kolkata, India*

Igor Kotenko 

*St. Petersburg Institute for Informatics and Automation of the Russian  
Academy of Sciences, St. Petersburg, Russia*

Lizhu Zhou

*Tsinghua University, Beijing, China*


More information about this series at <http://www.springer.com/series/7899>


Vladimir Voevodin · Sergey Sobolev (Eds.)

# Supercomputing

5th Russian Supercomputing Days, RuSCDays 2019  
Moscow, Russia, September 23–24, 2019  
Revised Selected Papers

*Editors*

Vladimir Voevodin   
Research Computing Center  
Moscow State University  
Moscow, Russia

Sergey Sobolev   
Research Computing Center  
Moscow State University  
Moscow, Russia

ISSN 1865-0929 ISSN 1865-0937 (electronic)  
Communications in Computer and Information Science  
ISBN 978-3-030-36591-2 ISBN 978-3-030-36592-9 (eBook)  
<https://doi.org/10.1007/978-3-030-36592-9>

© Springer Nature Switzerland AG 2019

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Preface

The 5th Russian Supercomputing Days Conference (RuSCDays 2019) was held September 23–24, 2019, in Moscow, Russia. It was dedicated to the 85th anniversary of academician V.V. Voevodin, the outstanding Russian mathematician who made a valuable contribution to the parallel computing theory and supercomputing technologies. The conference was organized by the Supercomputing Consortium of Russian Universities and the Russian Academy of Sciences. The conference organization coordinator was Moscow State University Research Computing Center.

The conference was supported by the Russian Foundation for Basic Research and our respected platinum educational partner (IBM), platinum sponsors (NVIDIA, T-Platforms, Lenovo), gold sponsors (Mellanox, Xilinx, AMD, RSC, Intel, Dell), and silver sponsors (NEC, EAS, DDN). The conference was organized in a partnership with the ISC High Performance conference series.

The RuSCDays conference series was born in 2015 as a union of several supercomputing event series in Russia and quickly became one of the most notable Russian supercomputing international meetings. The conference caters to the interests of a wide range of representatives from science, industry, business, education, government, and students – anyone connected to the development or the use of supercomputing technologies. The conference topics cover all aspects of supercomputing technologies: software and hardware design, solving large tasks, application of supercomputing technologies in industry, exaflops-scale computing issues, supercomputing co-design technologies, supercomputing education, and others.

All papers submitted to the conference were reviewed by three referees in the first review round. The papers were evaluated according to their relevance to the conference topics, scientific contribution, presentation, approbation, and related works description. After notification of conditional acceptance, the second review round was arranged which aimed at the final polishing of papers and also at the evaluating of authors' work based on the referees' comments. After the conference, the 60 best papers were carefully selected to be included in this volume.

The proceedings editors would like to thank all the conference committees members, especially the Organizing and Program Committee members as well as the referees and reviewers for their contributions. We also thank Springer for producing these high-quality proceedings of RuSCDays 2019.

October 2019

Vladimir Voevodin  
Sergey Sobolev

# Organization

## Steering Committee

V. A. Sadovnichiy (Chair)	Moscow State University, Russia
V. B. Betelin (Co-chair)	Russian Academy of Sciences, Russia
A. V. Tikhonravov (Co-chair)	Moscow State University, Russia
J. Dongarra (Co-chair)	University of Tennessee, USA
A. I. Borovkov	Peter the Great Saint-Petersburg Polytechnic University, Russia
VI. V. Voevodin	Moscow State University, Russia
V. P. Gergel	Lobachevsky State University of Nizhni Novgorod, Russia
G. S. Elizarov	NII Kvant, Russia
V. V. Elagin	Hewlett Packard Enterprise, Russia
A. K. Kim	MCST, Russia
E. V. Kudryashova	Northern (Arctic) Federal University, Russia
N. S. Mester	Intel, Russia
E. I. Moiseev	Moscow State University, Russia
A. A. Moskovskiy	RSC Group, Russia
V. Yu. Opanasenko	T-Platforms, Russia
G. I. Savin	Joint Supercomputer Center, Russian Academy of Sciences, Russia
A. S. Simonov	NICEVT, Russia
V. A. Soyfer	Samara University, Russia
L. B. Sokolinskiy	South Ural State University, Russia
I. A. Sokolov	Russian Academy of Sciences, Russia
R. G. Strongin	Lobachevsky State University of Nizhni Novgorod, Russia
A. N. Tomilin	Institute for System Programming of the Russian Academy of Sciences, Russia
A. R. Khokhlov	Moscow State University, Russia
B. N. Chetverushkin	Keldysh Institutes of Applied Mathematics, Russian Academy of Sciences, Russia
E. V. Chuprunov	Lobachevsky State University of Nizhni Novgorod, Russia
A. L. Shestakov	South Ural State University, Russia

## Program Committee

VI. V. Voevodin (Chair)	Moscow State University, Russia
R. M. Shagaliev (Co-chair)	Russian Federal Nuclear Center, Russia

M. V. Yakobovskiy (Co-chair)	Keldysh Institutes of Applied Mathematics, Russian Academy of Sciences, Russia
T. Sterling (Co-chair)	Indiana University, USA
S. I. Sobolev (Scientific Secretary)	Moscow State University, Russia
A. I. Avetisyan	Institute for System Programming of the Russian Academy of Sciences, Russia
D. Bader	Georgia Institute of Technology, USA
P. Balaji	Argonne National Laboratory, USA
M. R. Biktimirov	Russian Academy of Sciences, Russia
A. V. Bukhanovskiy	ITMO University, Russia
J. Carretero	University Carlos III of Madrid, Spain
Yu. V. Vasilevskiy	Keldysh Institutes of Applied Mathematics, Russian Academy of Sciences, Russia
V. E. Velikhov	National Research Center “Kurchatov Institute”, Russia
V. Yu. Volkonskiy	MCST, Russia
V. M. Volokhov	Institute of Problems of Chemical Physics of Russian Academy of Sciences, Russia
R. K. Gazizov	Ufa State Aviation Technical University, Russia
B. M. Glinskiy	Institute of Computational Mathematics and Mathematical Geophysics, Siberian Branch of Russian Academy of Sciences, Russia
V. M. Goloviznin	Moscow State University, Russia
V. A. Ilyin	National Research Center “Kurchatov Institute”, Russia
V. P. Ilyin	Institute of Computational Mathematics and Mathematical Geophysics, Siberian Branch of Russian Academy of Sciences, Russia
S. I. Kabanikhin	Institute of Computational Mathematics and Mathematical Geophysics, Siberian Branch of Russian Academy of Sciences, Russia
I. A. Kalyaev	NII MVS, South Federal University, Russia
H. Kobayashi	Tohoku University, Japan
V. V. Korenkov	Joint Institute for Nuclear Research, Russia
V. A. Kryukov	Keldysh Institutes of Applied Mathematics, Russian Academy of Sciences, Russia
J. Kunkel	University of Hamburg, Germany
S. D. Kuznetsov	Institute for System Programming of the Russian Academy of Sciences, Russia
J. Labarta	Barcelona Supercomputing Center, Spain
A. Lastovetsky	University College Dublin, Ireland
M. P. Lobachev	Krylov State Research Centre, Russia
Y. Lu	National University of Defense Technology, China
T. Ludwig	German Climate Computing Center, Germany

V. N. Lykosov	Institute of Numerical Mathematics, Russian Academy of Sciences, Russia
I. B. Meerov	Lobachevsky State University of Nizhni Novgorod, Russia
M. Michalewicz	University of Warsaw, Poland
L. Mirtaheri	Kharazmi University, Iran
S. G. Mosin	Kazan Federal University, Russia
A. V. Nemukhin	Moscow State University, Russia
G. V. Osipov	Lobachevsky State University of Nizhni Novgorod, Russia
A. V. Semyanov	Lobachevsky State University of Nizhni Novgorod, Russia
Ya. D. Sergeev	Lobachevsky State University of Nizhni Novgorod, Russia
H. Sithole	Centre for High Performance Computing, South Africa
A. V. Smirnov	Moscow State University, Russia
R. G. Strongin	Lobachevsky State University of Nizhni Novgorod, Russia
H. Takizawa	Tohoku University, Japan
M. Taufer	University of Delaware, USA
V. E. Turlapov	Lobachevsky State University of Nizhni Novgorod, Russia
E. E. Tyrtshnikov	Institute of Numerical Mathematics, Russian Academy of Sciences, Russia
V. A. Fursov	Samara University, Russia
L. E. Khaymina	Northern (Arctic) Federal University, Russia
T. Hoefler	Eidgenössische Technische Hochschule Zürich, Switzerland
B. M. Shabanov	Joint Supercomputer Center, Russian Academy of Sciences, Russia
L. N. Shchur	Higher School of Economics, Russia
R. Wyrzykowski	Czestochowa University of Technology, Poland
M. Yokokawa	Kobe University, Japan

## Industrial Committee

A. A. Aksenov (Co-chair)	Tesis, Russia
V. E. Velikhov (Co-chair)	National Research Center “Kurchatov Institute”, Russia
A. V. Murashov (Co-chair)	T-Platforms, Russia
Yu. Ya. Boldyrev	Peter the Great Saint-Petersburg Polytechnic University, Russia
M. A. Bolshukhin	Afrikantov Experimental Design Bureau for Mechanical Engineering, Russia
R. K. Gazizov	Ufa State Aviation Technical University, Russia



M. P. Lobachev	Krylov State Research Centre, Russia
V. Ya. Modorskiy	Perm National Research Polytechnic University, Russia
A. P. Skibin	Gidropress, Podolsk, Russia
S. Stoyanov	T-Services, Russia
A. B. Shmelev	RSC Group, Russia
S. V. Strizhak	Hewlett-Packard, Russia

## Educational Committee

V. P. Gergel (Co-chair)	Lobachevsky State University of Nizhni Novgorod, Russia
Vl. V. Voevodin (Co-chair)	Moscow State University, Russia
L. B. Sokolinskiy (Co-chair)	South Ural State University, Russia
Yu. Ya. Boldyrev	Peter the Great Saint-Petersburg Polytechnic University, Russia
A. V. Bukhanovskiy	ITMO University, Russia
R. K. Gazizov	Ufa State Aviation Technical University, Russia
S. A. Ivanov	Hewlett-Packard, Russia
I. B. Meerov	Lobachevsky State University of Nizhni Novgorod, Russia
V. Ya. Modorskiy	Perm National Research Polytechnic University, Russia
S. G. Mosin	Kazan Federal University, Russia
I. O. Odintsov	RSC Group, Russia
N. N. Popova	Moscow State University, Russia
O. A. Yufryakova	Northern (Arctic) Federal University, Russia

## Organizing Committee

Vl. V. Voevodin (Chair)	Moscow State University, Russia
V. P. Gergel (Co-chair)	Lobachevsky State University of Nizhni Novgorod, Russia
B. M. Shabanov (Co-chair)	Joint Supercomputer Center, Russian Academy of Sciences, Russia
S. I. Sobolev (Scientific Secretary)	Moscow State University, Russia
A. A. Aksenov	Tesis, Russia
A. P. Antonova	Moscow State University, Russia
A. S. Antonov	Moscow State University, Russia
K. A. Barkalov	Lobachevsky State University of Nizhni Novgorod, Russia
M. R. Biktimirov	Russian Academy of Sciences, Russia
Vad. V. Voevodin	Moscow State University, Russia
T. A. Gamayunova	Moscow State University, Russia
O. A. Gorbachev	RSC Group, Russia

V. A. Grishagin	Lobachevsky State University of Nizhni Novgorod, Russia
S. A. Zhumatiy	Moscow State University, Russia
V. V. Korenkov	Joint Institute for Nuclear Research, Russia
I. B. Meerov	Lobachevsky State University of Nizhni Novgorod, Russia
D. A. Nikitenko	Moscow State University, Russia
I. M. Nikolskiy	Moscow State University, Russia
N. N. Popova	Moscow State University, Russia
N. M. Rudenko	Moscow State University, Russia
A. S. Semenov	NICEVT, Russia
I. Yu. Sidorov	Moscow State University, Russia
L. B. Sokolinskiy	South Ural State University, Russia
K. S. Stefanov	Moscow State University, Russia
V. M. Stepanenko	Moscow State University, Russia
N. T. Tarumova	Moscow State University, Russia
A. V. Tikhonravov	Moscow State University, Russia
A. Yu. Chernyavskiy	Moscow State University, Russia
P. A. Shvets	Moscow State University, Russia
M. V. Yakobovskiy	Keldysh Institutes of Applied Mathematics, Russian Academy of Sciences, Russia



# Contents

## Parallel Algorithms

A Highly Parallel Approach for Solving Computationally Expensive Multicriteria Optimization Problems . . . . .	3
<i>Victor Gergel and Evgeny Kozinov</i>	
Data-Parallel High-Precision Multiplication on Graphics Processing Units . . .	15
<i>Konstantin Isupov, Alexander Kuvaev, and Vladimir Knyazkov</i>	
Efficiency of Basic Linear Algebra Operations on Parallel Computers . . . . .	26
<i>Igor Konshin</i>	
Explicit-Implicit Schemes for Parallel Solving of the Suspension Transport Problems in Coastal Systems . . . . .	39
<i>Alexander I. Sukhinov, Alexander E. Chistyakov, Valentina V. Sidoryakina, and Elena A. Protsenko</i>	
GPU Implementation of a Stencil Code with More Than 90% of the Peak Theoretical Performance. . . . .	51
<i>Ilya Pershin, Vadim Levchenko, and Anastasia Perepelkina</i>	
Memory-Optimized Tile Based Data Structure for Adaptive Mesh Refinement . . . . .	64
<i>Anton Ivanov, Anastasia Perepelkina, Vadim Levchenko, and Ilya Pershin</i>	
Multithreaded Multifrontal Sparse Cholesky Factorization Using Threading Building Blocks . . . . .	75
<i>Rostislav Povelikin, Sergey Lebedev, and Iosif Meyerov</i>	
Optimal Packings of Congruent Circles on a Square Flat Torus as Mixed-Integer Nonlinear Optimization Problem. . . . .	87
<i>Vladimir Voloshinov and Sergey Smirnov</i>	
Parallel Global Optimization for Non-convex Mixed-Integer Problems. . . . .	98
<i>Konstantin Barkalov and Ilya Lebedev</i>	
Parallel Ray Tracing Algorithm for Numerical Analysis of Laser Radiation Absorption in a Plasma . . . . .	110
<i>Alexey Kotelnikov, Ilia Tsygvintsev, Mikhail Yakobovsky, and Vladimir Gasilov</i>	

Porting CUDA-Based Molecular Dynamics Algorithms to AMD ROCm Platform Using HIP Framework: Performance Analysis . . . . .	121
<i>Evgeny Kuznetsov and Vladimir Stegailov</i>	
Solving of Eigenvalue and Singular Value Problems via Modified Householder Transformations on Shared Memory Parallel Computing Systems. . . . .	131
<i>Andrey Andreev and Vitaly Egunov</i>	
<b>Supercomputer Simulation</b>	
Analysis of the Influence of Changes in the Exterior Elements of the Car on the Drag Coefficient and the Problem of Its Optimization . . . . .	155
<i>Aleksei Maksimov, Yuri Boldyrev, Aleksei Borovkov, Aleksei Tarasov, Oleg Klyavin, and Ilya Davydov</i>	
Application of High-Performance Computing for Modeling the Hydrobiological Processes in Shallow Water . . . . .	166
<i>Alexander I. Sukhinov, Alexander E. Chistyakov, Alla V. Nikitina, Alena A. Filina, and Yulia V. Belova</i>	
Computer Simulation of Endothermic Decomposition of High-Energy Substances $C_xH_yN_mO_n$ . Substance Composition Optimization . . . . .	182
<i>Vadim Volokhov, Alexander Volokhov, Dmitry Varlamov, Elena Amosova, Tatyana Zyubina, Pavel Toktaliev, and Sergey Martynenko</i>	
Coupling of PDE and ODE Solvers in INMOST Parallel Platform: Application to Electrophysiology. . . . .	193
<i>Alexey Chernyshenko, Alexander Danilov, and Vasily Kramarenko</i>	
Digital Rock Modeling of a Terrigenous Oil and Gas Reservoirs for Predicting Rock Permeability with Its Fitting Using Machine Learning . . .	203
<i>Vladimir Berezovsky, Ivan Belozarov, Yungfeng Bai, and Marsel Gubaydullin</i>	
Digital Twin of the Seismogeological Object: Building and Application. . . . .	214
<i>Vladimir Cheverda, Dmitry Kolyukhin, Vadim Lisitsa, Maksim Protasov, Galina Reshetova, Anastasiya Merzlikina, Victoriay Volyanskaya, Denis Petrov, Valery Shilikov, Artjem Melnik, Boris Glinisky, Igor Chernykh, and Igor Kulikov</i>	
GPU-Based Discrete Element Modeling of Geological Faults . . . . .	225
<i>Vadim Lisitsa, Dmitriy Kolyukhin, Vladimir Tcheverda, Victoria Volianskaia, and Viatcheslav Priimenko</i>	

High Performance Parallel Simulations of Subsurface Radar Sounding of Celestial Bodies . . . . .	237
<i>Yaroslav Ilyushin</i>	
High-Performance Hybrid Computing for Bioinformatic Analysis of Protein Superfamilies. . . . .	249
<i>Dmitry Suplatov, Yana Sharapova, Maxim Shegay, Nina Popova, Kateryna Fesko, Vladimir Voevodin, and Vytas Švedas</i>	
Improving Parallel Efficiency of a Complex Hydrogeological Problem Simulation in GeRa. . . . .	265
<i>Dmitry Bagaev, Fedor Grigoriev, Ivan Kapyrin, Igor Konshin, Vasily Kramarenko, and Andrey Plenkin</i>	
Morphing and Wave Perturbations in Distinguishing Molecular Clouds' Collision. . . . .	278
<i>Boris Rybakin and Valery Goryachev</i>	
Numerical Experiments with Digital Twins of Core Samples for Estimating Effective Elastic Parameters . . . . .	290
<i>Galina Reshetova, Vladimir Cheverda, and Tatyana Khachkova</i>	
Orange Carotenoid Protein Absorption Spectra Simulation Using the Differential Evolution Algorithm . . . . .	302
<i>Roman Pishchalnikov, Igor Yaroshevich, Eugene Maksimov, Nikolai Sluchanko, Alexey Stepanov, David Buhrke, and Thomas Friedrich</i>	
Parallel Dynamic Mesh Adaptation Within INMOST Platform . . . . .	313
<i>Kirill Terekhov</i>	
Parallel Implementation of Coupled Wave and Bottom Deposit Transportation Models to Simulate Surface Pollution Areas . . . . .	327
<i>Alexander Sukhinov, Alexander Chistyakov, Elena Protsenko, Valentina Sidoryakina, and Sofya Protsenko</i>	
Recovery of the Permittivity of an Anisotropic Inhomogeneous Body in a Rectangular Waveguide . . . . .	339
<i>Medvedik Mikhail, Moskaleva Marina, and Smirnov Yuri</i>	
Relativistic Hydrodynamics Modeling by Means Adaptive Nested Mesh on IBM Power 9. . . . .	350
<i>Igor Kulikov, Igor Chernykh, Evgeny Berendeev, Dmitry Karavaev, and Viktor Protasov</i>	
Search for Approaches to Supercomputer Quantum-Chemical Docking . . . . .	363
<i>Alexey Sulimov, Danil Kutov, Anna Gribkova, Ivan Ilin, Anna Tashchilova, and Vladimir Sulimov</i>	

Simulation of “ExoMars” Spacecraft Landing on the Surface of Mars Using Supercomputer Technologies . . . . .	379
<i>Anuar Kagenov, Sergey Prokhanov, Anatoliy Glazunov, Ivan Eremin, Kirill Kostyushin, Konstantin Zhilcov, Iliya Tyryshkin, and Sergey Orlov</i>	
Solving Inverse Problems of Ultrasound Tomography in a Nondestructive Testing on a Supercomputer . . . . .	392
<i>Eugene Bazulin, Alexander Goncharsky, and Sergey Romanov</i>	
Supercomputer Modelling of Spatially-heterogeneous Coagulation using MPI and CUDA . . . . .	403
<i>Rishat Zagidullin, Alexander Smirnov, Sergey Matveev, and Eugene Tyrtysnikov</i>	
Supercomputing the Seasonal Weather Prediction . . . . .	415
<i>Rostislav Fadeev, Konstantin Ushakov, Mikhail Tolstykh, Rashit Ibrayev, Vladimir Shashkin, and Gordey Goyman</i>	
The Creation of Intelligent Support Methods for Solving Mathematical Physics Problems on Supercomputers . . . . .	427
<i>Boris Glinskiy, Yury Zagorulko, Galina Zagorulko, Igor Kulikov, and Anna Sapetina</i>	
The Parallel Implementation of the Adaptive Mesh Technology in Poroelasticity Problems . . . . .	439
<i>Sergey Kalinin, Dmitry Karavaev, and Anna Sapetina</i>	
The Simulation of 3D Wave Fields in Complex Topography Media . . . . .	451
<i>Pavel Titov</i>	
Three-Dimensional Ultrasound Tomography: Mathematical Methods and Experimental Results . . . . .	463
<i>Alexander Goncharsky and Sergey Seryozhnikov</i>	
Validation of the Regional Climate Model for the South of Russia . . . . .	475
<i>Alexander Titov, Alexander Khoperskov, Konstantin Firsov, Sergey Khoperskov, and Tatiana Chesnokova</i>	
<b>HPC, BigData, AI: Architectures, Technologies, Tools</b>	
An Experimental Study of Deep Neural Networks on HPC Clusters . . . . .	489
<i>Dmitry Buryak, Nina Popova, Vladimir Voevodin, Yuri Konkov, Oleg Ivanov, Denis Shaykhlislamov, and Ilya Fateev</i>	
Artificial Intelligence Problems in Mathematical Modeling . . . . .	505
<i>Valery Il'in</i>	

Aspect-Oriented Set@I Language for Architecture-Independent Programming of High-Performance Computer Systems . . . . .	517
<i>Ilya I. Levin, Alexey I. Dordopulo, Ivan V. Pisarenko, and Andrey K. Melnikov</i>	
Bridging the Gap Between Applications and Supercomputing: A New Master's Program in Computational Science . . . . .	529
<i>Iosif Meyerov, Alexander Sysoyev, Anna Pirova, Natalia Shestakova, and Mikhail Ivanchenko</i>	
DLI: Deep Learning Inference Benchmark . . . . .	542
<i>Valentina Kustikova, Evgenii Vasiliev, Alexander Khvatov, Pavel Kumbrasiev, Roman Rybkin, and Nadezhda Kogteva</i>	
Educational Course "Introduction to Deep Learning Using the Intel neon Framework" . . . . .	554
<i>Valentina Kustikova, Nikolay Zolotykh, and Maxim Zhiltsov</i>	
Evaluation of Intel Memory Drive Technology Performance for Computational Astrophysics . . . . .	563
<i>Igor Chernykh, Vladimir Mironov, Andrey Kudryavtsev, and Igor Kulikov</i>	
Extended Routing Table Generation Algorithm for the Angara Interconnect . . . . .	573
<i>Anatoly Mukosey, Alexey Simonov, and Alexander Semenov</i>	
High-Performance Solution of the Two-Class SVM Problem for Big Data Sets by the Mean Decision Rule Method . . . . .	584
<i>Mikhail Kurbakov, Alexandra Makarova, and Valentina Sulimova</i>	
Performance and Scalability of Materials Science and Machine Learning Codes on the State-of-Art Hybrid Supercomputer Architecture . . . . .	597
<i>Nikolay Kondratyuk, Grigory Smirnov, Alexander Agarkov, Anton Osokin, Vsevolod Nikolskiy, Alexander Semenov, and Vladimir Stegailov</i>	
Performance of the Particle-in-Cell Method with the Intel (Broadwell, KNL) and IBM Power9 Architectures. . . . .	610
<i>Evgeny Berendejev, Alexey Snytnikov, and Anna Efimova</i>	
Software Development Tools for FPGA-Based Reconfigurable Systems Programming . . . . .	625
<i>Ilya Levin, Alexey Dordopulo, Vyacheslav Gudkov, Andrey Gulenok, Alexander Bovkun, Georgyi Yevstafiyev, and Kirill Alekseev</i>	

Software <i>Q</i> -system for the Research of the Resource of Numerical Algorithms Parallelism. . . . .	641
<i>Valentina Aleeva, Ekaterina Bogatyreva, Artem Skleznev, Mikhail Sokolov, and Artemii Shuppa</i>	
The Role of Student Projects in Teaching Machine Learning and High Performance Computing. . . . .	653
<i>Andrey Sozykin, Anton Koshelev, and Dmitry Ustalov</i>	
<b>Distributed and Cloud Computing</b>	
Budget and Cost-Aware Resources Selection Strategy in Cloud Computing Environments . . . . .	667
<i>Victor Toporkov, Andrei Tchernykh, and Dmitry Yemelyanov</i>	
Building an Algorithmic Skeleton for Block Data Processing on Enterprise Desktop Grids. . . . .	678
<i>Sergei Vostokin and Irina Bobyleva</i>	
Roadmap for Improving Volunteer Distributed Computing Project Performance . . . . .	690
<i>Vladimir Yakimets and Ilya Kurochkin</i>	
SAT-Based Cryptanalysis: From Parallel Computing to Volunteer Computing. . . . .	701
<i>Oleg Zaikin</i>	
Supporting Efficient Execution of Workflows on Everest Platform . . . . .	713
<i>Oleg Sukhoroslov</i>	
Start-up and the Results of the Volunteer Computing Project RakeSearch . . .	725
<i>Maxim Manzyuk, Natalia Nikitina, and Eduard Vatutin</i>	
Use of a Desktop Grid to Effectively Discover Hits in Virtual Drug Screening. . . . .	735
<i>Evgeny Ivashko and Natalia Nikitina</i>	
<b>Author Index . . . . .</b>	<b>745</b>