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International Master's degree program "High-Performance and distributed information processing systems"

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Abstract

This paper presents information on the content and resources of the internationally certified Master's program "High-Performance and Distributed Information Processing Systems" in the field of Applied Mathematics and Computer Science. The paper studies scientific achievements of the academic staff, peculiarities of courses currently held, characteristics of available facilities and resources, prospects for the Master's worldwide research activities at a high scientific level, and opportunities to pursue postgraduate studies and to defend a PhD thesis.

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Keywords: Master's Program; curriculum; core courses description; parallel and distributed programming; high-performance computing; data mining

1. Introduction

In accordance with the Development Strategy of the Information Technology Industry of the Russian Federation in 2014-2020 projected for the year of 2025 (hereinafter referred to as the Strategy) approved by the Russian Federation Government Executive Order No. 2036-r dated November 1, 2013, the Priority Research and Development Areas in the field of Information Technology include the following:

- Big Data analysis and data mining including new methods and algorithms for Big Data collecting, storing and mining, new methods and software for distributed Big Data processing, as well as new methods and software for predictive modeling of complex engineering solutions;

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- development of new high-performance computing and data storing systems including new algorithms for parallel computing, new supercomputing technologies and applications, new communication technologies and communication protocols for increasing energy efficiency and fail safety, and for lowering the time of exchange between system elements, as well as new software for high-performance and reliable data storage systems;

- ubiquitous and cloud computing including new intercommunication algorithms for off-line devices (such as mobile and transport), new algorithms for interaction between robot systems and human beings, new engineering elements of a network data transfer infrastructure, new integrated sensors and sensor networks, as well as new infrastructure and software elements for implementation of various patterns of cloud service delivery.

The key issue of modern Information Technology is Big Data mining – a processing technology for large amounts of data of various composition (being very often updated and located in different sources) providing transfer from the common use of data assets to their capitalization: identification of future needs, creation of new products and services, improving competitiveness, development of completely new approaches to solve complex interdisciplinary basic and applied problems almost in all areas of human activities. International Data Corporation (www.idc.com, www.idcrussia.com) indicates that operation with Big Data will be one more ‘must-have’ competence in the world of today.

The IT industry is one of the most dynamically developing industries throughout the world and in Russia. The global IT market is estimated at 1.7 US dollars trillion. According to forecasts, the global IT market will continue to grow in the coming years averagely by at least 5 percent per year. Furthermore, the Russian IT industry has the potential for significantly faster growth of 10 percent or even more per year.

The Strategy’s measures include increasing by 2020 the number of high-tech jobs in the Russian IT industry up to 700 thousand (about 60 thousand annually) workplaces, as well as the annual increase in domestic IT production and services of not less than 1 billion US dollars.

In order to provide rates of growth of priority research and development areas in the IT industry with high-qualified personnel, Samara National Research University (Samara University, before 2016 – Samara State Aerospace University) together with the Image Processing Systems Institute of the Russian Academy of Sciences (IPSI RAS) – the Branch of the “Crystallography and Photonics” Federal Research and Development Center of the RAS [1] have developed the Master’s degree program “High-Performance and Distributed Information Processing Systems” (hereinafter referred to as the Master’s program).

The Master’s program was developed within a framework of the National Education and Training System in the field of Supercomputer Technologies and High-Performance Computing (HPC) being implemented by the Supercomputer Consortium of Russian Universities (www.hpc-russia.ru, www.parallel.ru) whose permanent member from 2012 has been Samara University (The Consortium President – Rector of M.V. Lomonosov Moscow State University V.A. Sadovnichy).

The advantage of the Master's program is that it is based on scientific achievements of the Russian leading scientific school “Diffractive Nanophotonics and Computer Optics” under the leadership of the Academician of the RAS V.A. Soifer [2-11]. Beginning with the first course of scientific schools (1996), the projects headed by V.A. Soifer frequently obtained the state support. In particularly, in 2016 the Project “Theory Development and Creation of Photonics Elements for All-Optical Information Processing” was supported by a two-year grant of the President of the Russian Federation in Information and Telecommunication Systems and Technology.

From 2012, the Master’s program has been implemented at the Faculty of Information Technology of Samara University in the field Applied Mathematics and Computer Science. In 2015 the Master’s program was internationally accredited by the Accreditation Center of Association for Engineering Education of Russia (AEER) with releasing the AEER Certificate and the Certificate of the European Network for Accreditation in Engineering Education (ENAEE) on rewarding this program with the European Quality Label (EUR-ACE® Label). The Master’s program has been recorded in the register of AEER accredited programs and listed on the ENAEE database (www.ac-raee.ru, www.eur-ace.eu).

Fig. 1. Academician of the RAS, Doctor of Engineering, Professor V.A. Soifer.

АССОЦИАЦИЯ ИНЖЕНЕРНОГО ОБРАЗОВАНИЯ РОССИИ

СЕРТИФИКАТ

ПРОФЕССИОНАЛЬНО-ОБЩЕСТВЕННОЙ АККРЕДИТАЦИИ ОБРАЗОВАТЕЛЬНЫХ ПРОГРАММ В ОБЛАСТИ ТЕХНИКИ И ТЕХНОЛОГИЙ

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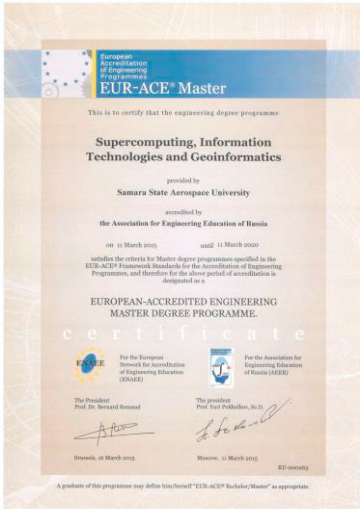

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Fig.2. Certificates of Accredetation.

The Master's program director is a well-known scientist, Doctor of Physics and Mathematics, Professor, Director of the IPSI RAS N.L. Kazanskiy.

Fig. 3. Doctor of Phisycs and Mathematics, Professor N.L. Kazanskiy.

The areas of scientific interests of Professor N.L. Kazanskiy are as follows: Computing Experiment [12-17]; Computer Optics [18-42] including Engineering Applications [29, 30]; Diffractive Microrelief Formation Processes Modeling [31-38] and Asymptotic Analytical Studies [39-42]; Computer Vision Systems [43-45]; Diffractive Nanophotonics [46-49].

Professor N.L. Kazanskiy is the author and co-author of more than 400 research papers including 12 monographs, one textbook, 8 learning guides, and 57 invention patents including three Eurasian patents. The Hirsch index in Scopus international database is 26 (Author ID: 35581405600); the Russian Science Citation Index (e-library.ru; AuthorID: 10690): 392 publications, 4485 references, Hirsch index – 34, i10-index – 120.

The following leading scientists from the Specialized Department “High-Performance Computing” of the IPSI RAS have been actively involved into education activities: Head of the Department, Doctor of Physics and Mathematics, Professor N.L. Kazanskiy; Doctor of Engineering, Professor S.B. Popov; Doctor of Engineering, Professor A.V. Kupriyanov; Doctor of Physics and Mathematics, Professor D.L. Golovashkin; Doctor of Engineering, Professor V.A. Fursov; Doctor of Physics and Mathematics, Associate Professor P.G. Serafimovich [50]; Doctor of Engineering, Professor A.V. Nikonorov; Doctor of Engineering, Professor N.Yu. Ilyasova; Doctor of Engineering, Professor A.N. Kovartsev; Doctor of Engineering, Professor S.V. Vostokin.

2. General Descripnion

Type of education: full-time study.
Program duration: 2 academic years to complete.
Program workload: 120 ECTS credits.
Degree awarded: Master of Science.

Program objective. The Master’s program objective is to train highly qualified specialists being aware of advanced methods, expertise, knowledge, and skills in the field of software tools and technology of parallel programming, high-performance computing, grid-technologies, and distributed information processing technology.

Educational process. The Master’s program students are provided with the following opportunities:

- to work in laboratories equipped with the most-up-to-date training, process and research equipment;
- to use advanced high-performance computer facilities to perform scientific and experimental research;
- to use professional software in training and research activities;
- to undertake internships in leading Russian and global companies and research and development centers;
- to be pursuing a Master’s degree on other similar Master’s programs in leading Russian and global universities.

Different on-line training methods and distant learning techniques are widely used in educational process.

Training is provided both in accordance with a basic academic curriculum and according to individual training programs in English. It is also possible to have accelerated intensive training courses.

Professional skills. Learning on the Master’s program enables the graduates to develop the following professional skills:

- capability to study information systems using mathematical modeling , forecasting and system analysis methods;
- capability to investigate Big Data systems using up-to-date high-performance, distributed and cloud computing methods;
- capability to use state-of-the-art High-Performance Computers in pursuing research and development;
- foreign language skills as a tool for professional communication.

Additional professional competences matching the Master’s program specialization are as follows:

- capability to develop, research and use complex mathematical and physical models for qualitative and quantitative description of phenomena and processes, and to develop new software solutions to obtain particular results;
- capability to use up-to-date data processing, analysis, representation, and transfer methods including database mining and Big Data processing technologies;
- capability to design and develop corporative information Business Management Systems based on industrial distributed programming technology.

Areas of professional activities. Professional-oriented focus areas of the Master’s program include the following fields and subjects of professional activities of the postgraduates:

Areas of professional activities of holders of a Master’s degree:

- models of physical, information, engineering, and socio-economic systems including mathematical, simulation, functional modeling, and system analysis;
- programming techniques such as: parallel, distributed, off-line, functional programming;
- software engineering including software design and production;
- reliability, capacity and security of information systems and networks;
- organizational approaches and forms of scientific research including its automation.

Subjects of professional activities of holders of a Master's degree:

- software systems including: computer, automatically controlled, telecommunication and information systems, information resources and technologies;
- mathematical, simulation and information models of systems and processes;
- methods and software tools for software design and implementation;
- innovations and innovation processes in the field of information and communication technologies;
- research-and-development and design-and-experimental projects in the field of Applied Mathematics and development of innovative Information Technology;
- software and information applications for computer facilities, networks and information systems;
- lifecycle models and processes of information systems;
- algorithms, libraries and software suites;
- standards, profiles, open sources, architectural methods for specification of IT systems and services.

Admission procedure. To enroll at the Master's program it is necessary to have a document confirming your previous basic education in Physics and Mathematics and to meet face-to-face for an interview to show your individual advances. Thus the following conditions should be taken into consideration: experience in research and development (publications, project involvement), practical experience, documents confirming your individual advances (diplomas, professional certificates, diplomas of winners and prize-winners of Olympiads and scientific competitions, grants). CVs should be applied beforehand.

3. Curriculum

The Master's program curriculum structure is shown in Table 1 where 1 ECTS credit equals to 36 academic hours, and the basic training courses focused on the program specialization are marked with an *asterisk.

Table 1. Curriculum Structure of the Master's Degree Program "High-Performance and Distributed Information Processing Systems".

Educational Units and Courses	Semester	Form of Examination	ECTS credits
Obligatory Courses			
Foreign language	1 2	Pass/Fail Exam	4
History and Methodology of Applied Mathematics and Computer Science	1 2	Pass/Fail Exam	4
Mathematical Modeling *	1 2	Exam Exam	11
Data Mining *	1 2	Exam Pass/Fail	9
Parallel Programming Software Tools and Technologies *	1	Exam	5
Software for Multiprocessor Computer Systems *	1	Pass/Fail	4
Modern Methods and Algorithms for Solving Complicated Problems on Supercomputers*	2	Exam	4
Distributed Programming Technology*	3	Exam	6

Grid Technologies and Cloud Computing *	3	Pass/Fail	4
Elective Courses			
Architectures of Modern Parallel Computing Systems Fundamentals of Telecommunications	3	Exam	4
Distributed Data Processing in Modern DBMS Video Stream Processing Technologies	2	Pass/Fail	3
Modeling and Analysis of Parallel Algorithms Visual Parallel Programming Methods and Software; Automatic Programming	3	Pass/Fail	4
Parallel Distributed Applications Design Programming Complex Design	3	Pass/Fail	5
Master's Scientific Research	1 2 3	Diff Diff Diff	9 8 9
Internship	4	Diff	18
Thesis	4	Defense	9
Total			120

4. Core Courses Description

4.1. Mathematical Modeling

Course objective: Study of development, research and application methods for mathematical models of physical, chemical, biological, and other scientific and technical objects, as well as social and economic systems.

Syllabus:

Simplest models. Model development methods.

Building mathematical models based on the law of matter conservation.

Building mathematical models based on the law of conservation of energy.

Building mathematical models based on the law of conservation of number of particles. Joint application of several basic laws.

Models of hard formalized objects, analogy examples between mechanical, thermodynamic and economic objects.

Mathematical models in Economics. Competition models.

Statistical modeling. Clusters and fractals in mathematical modeling.

System approach in mathematical modeling. Big and small systems. Principles of mathematical modeling.

Mathematical models of nonlinear objects and processes.

Study of systems' qualitative behavior. Stability of dynamic systems. Stability of periodic solutions. Orbital stability.

Classification of critical points. Phase patterns of conservative systems. Limit cycles.

Influence of control parameters on systems dynamics. Bifurcations of nonlinear dynamic systems. Bifurcation of stability change. Dynamic chaos.

Asymptotic methods of investigation of mathematical models. Asymptotic expansions. Elementary perturbation theory, regular and singular perturbations.

Model decomposition of diverse systems. Integral varieties and simplified model building. Decomposition of linear systems. Decomposition of nonlinear systems.

4.2. Data Mining

Course objective: Study of Data Mining algorithms and software; study of software tools, algorithms and programs for Big Data collection, storage, search, analysis, and visualization; study of basic architectures of NoSQL databases and hands-on experience in the field of software infrastructure of Hadoop distributed computing framework.

Syllabus:

Overview of modern Data Mining techniques.

Problems of data statistical analysis and experiment planning. Input and output factors.

Methods of correlation and regression analysis. Properties of OLS estimates of linear regression parameters.

Dispersion analysis. Fisher statistics. SS Technology.

Experiment planning. Plan optimality criteria.

Image recognition. Linear and nonlinear classification.

Methods of building decision rules for classification. Stochastic approximation methods. Robbins-Monro stochastic approximation procedure.

Algorithms of automatic learning and clustering. Algorithm of k-intragroup averages.

Basics of neural networks. Building and training neural networks. Back propagation algorithm.

Big Data concept, problems and challenges. Definitions of Big Data, technology and architecture. New methods of data handling. Examples of innovative application of Big Data Technology.

Basics of software infrastructure in Hadoop distributed computing framework. Basic definitions for Hadoop and Hadoop Distributed File System (HDFS). Hadoop high-layer distributed computing frameworks – Pig & Hive. Cluster resource management and YARN job scheduling framework. Process coordination service for ZooKeeper distributed applications.

MapReduce distributed computing paradigm. Basic algorithms and design patterns (patterns) in the MapReduce paradigm. Basics of MapReduce-application programming in Hadoop environment. Basics of graph computing in the MapReduce paradigm.

NoSQL databases. Basics of distributed databases and the CAP theorem. Main types of NoSQL databases. Hbase open distributed NoSQL DBMS. Couchbase document database.

Basic data stream processing techniques. Apache Spark platform. Storm platform. IBM Streams platform.

4.3. Parallel Programming Software Tools and Technologies

Course objective: Study of approaches, methods and development tools for application software for parallel computing systems with diverse architecture and special development equipment for parallel programming.

Syllabus:

Architecture of parallel computing systems. Parallel programming models.

Design techniques of parallel applications: decomposition, communication, integration, displaying.

Performance analysis of parallel applications.

Software tools for creating parallel applications using the MPI library: organization and basic functions, collective functions, insure of modularity, communicators, virtual topologies, use of different data types.

Main parallel programming patterns for shared memory systems. Basic approach to the process of optimization of applications performance using parallel programming equipment. Overview of analytics tools for parallelism performance and implementation.

OpenMP parallel programming standard for shared memory systems: principles and fundamental components, directives, function library, environment variables.

Parallel programming instruments for shared memory systems – Intel Threading Building Blocks (Intel® TBB) library and Cilk Plus parallel programming language.

Special development equipment for parallel programming: ScaLAPACK, PVM, T-System.

4.4. Software for Multiprocessor Computer Systems

Course objective: Study of software intended for control, monitoring and setting-up computer cluster systems, research of architectural decisions and building principles for big cluster systems.

Syllabus:

Preparing Cluster User Environment.

Using Cluster MPI Technology.

Using Cluster OpenMP Technology.

Network File Systems (NFS).

Using NFS.

Cluster monitoring.

Torque Portable Batch System. Setting-up and using Torque.

Typical tasks for Cluster Administration.

4.5. Modern Methods and Algorithms for Solving Complicated Problems on Supercomputers

Course objective: Study of parallel computing methods and algorithms to solve problems of computing mathematics and physics.

Syllabus:

Sequential programs parallelizing: acyclic and cyclic program parts parallelizing, expressions parallelizing.

Synthesis of parallel algorithms: bottom-up and top-down approaches. Characteristics of parallel computing processes and algorithms.

Parallel algorithms for matrix multiplication. Parallel algorithms for solving general simultaneous linear algebraic equations (SLAE) based on iterative methods. Parallel algorithms for solving general SLAEs based on direct methods. Parallel algorithms for solving SLAEs with band matrices based on colliding beam methods, cyclic reduction and domain decomposition. Parallel algorithms for solving SLAEs with triangular matrices.

Parallel algorithms for solving finite-difference equations of explicit difference schemes. Parallel algorithms for solving finite-difference equations of implicit difference schemes. Application of linear net domain decomposition. Application of cyclic net domain decomposition.

Difference solution of Maxwell equations using a domain decomposition method.

Solving problems of Computer Optics on Graphic Processing Units (GPU).

4.6. Distributed Programming Technology

Course objective: Study of features of Enterprise Distributed Software Systems and principles of their implementation within the scope of Java Enterprise Edition Technology, study of design principles for software and related technologies.

Syllabus:

Distributed programming systems.

JavaEE model.

Basics of Java programming language.

Computer assisted design techniques.

XML, JNDI, JDBC, Servlets, JSP, EJB 2, Session Beans, Entity Beans, MDB, Hibernate, EJB 3, Entity Persistence, JSF,

Web Services, JTA, RUP.

4.7. Grid Technologies and Cloud Computing

Course objective: Study of state-of-the-art computer cluster systems, grid systems, cloud computing, architectural solutions, and building-up principles for large-scale computing systems.

Syllabus:

Distributed systems. Cluster computing and supercomputing.

Basics of grid technology and cloud computing. Interconnection of grid computing and cloud computing models. Grid computing and cloud computing compatibility. Grid and cloud modeling and simulation.

Levels and types of cloud computing. Virtualization. Internet services and service-oriented architecture. Cloud computing standards. Cloud computing security. Cloud computing platforms. Google Cloud platform and Amazon web services.

Data-intensive computing. Data storage systems. Separated, distributed and parallel file systems. Parallel input/output.

MPI specification.

OpenMP specification.

MapReduce technology, technology properties.

Hadoop distributed file system. Programming in Hadoop framework.

MapReduce frameworks in Image Processing and Nanophotonics.

Cloud computing for GPU systems.

Integration of hybrid computing resources based on cloud environments.

5. Resourcing

5.1. Computing Equipment

5.1.1. Supercomputer "Sergey Korolyov"

Manufacturer: IBM.

Basic technical specifications:

- total number of servers/processors/compute cores: 179/360/1952;
- total number of GPUs /cores: 5/4288;
- common RAM: 5018 GB;
- type of system area network: QLogic/Voltaire InfiniBand DDR, QDR;
- type of control network: Gigabit Ethernet;
- operating system: Red Hat Enterprise Linux 5.11;
- peak performance 30 Tflops.

Objective: scientific research and training of world-class specialists using scientific and educational supercomputing and grid technologies including nanotechnology, creation of competitive samples of new equipment.

5.1.2. Multicomputer System (Cluster) for Parallel and Distributed Computing and Data Storage

Manufacturers: Super Micro Computer Inc., Mellanox Technologies Inc., Hewlett-Packard Enterprise.

Computer cluster technical specifications:

- number of computation nodes – 46;
- number of compute cores for CPU – 1264;
- GPU-accelerators – NVidia Kepler K40m - 3;
- accelerators – Intel Xeon Phi 7120P – 3;
- integral RAM capacity– 11.5 TB;
- integral HD memory capacity – 140 TB;

- supercomputer peak performance – 30 TFLOPS.

Objective: solution of computational problems within the framework of quantum-mechanical calculations with the help of specialized programs VASP, Crystal, Wien2k, Siesta, Quantum Espresso, GAUSSIAN09, LAMMPS, CP2K, computing data storage.

Fig. 4. Supercomputer “Sergey Korolyov”.

Fig. 5. Multicomputer system (cluster) for parallel and distributed computing and data storage.

5.1.3. HP Computer Cluster

Manufacturer: Hewlet Packard.

Cluster system in HP BLc3000 Twr CTO Enclosure is constructed on the basis of HP ProLiant BL260c control server and seven HP ProLiant 2xBL220c blade servers. Cluster peak performance is about 1.5 Tflops.

The computer cluster is used to solve modeling and designing problems for nanostructures, nonlinear optical modeling, distributed processing, and very-fine image file storage.

5.1.4. Portable Supercomputer PS ECM 1

Manufacturer: Russian Federal Nuclear Center in Sarov (All-Russia Research Institute of Experimental Physics (ARRIEP)).

A general purpose supercomputer is intended for a wide range of engineering solutions. Its peak performance is 1.1 Tflops in double-precision arithmetic operations. The supercomputer is based on 12-core AMD processors and includes three 4-socket motherboards. Thus, the system contains 144 processor cores. Each motherboard has 128

GB RAM; the shared memory is 384 GB. InfiniBand adaptor switchless intercommunication is used as a high-performance communication medium to transfer interprocess messages.

Fig. 6. HP Computer Cluster.

Fig. 7. Portable supercomputer PS ECM 1.

5.2. Data Storage Systems

Data storage systems consist of servers, disk stores and a network infrastructure for high-performance systems.

Current configuration of a data storage system includes the following:

- IBM DS3400, capacity of 7.2 TB, connected to the HPC cluster “Sergey Korolyov”;
- IBM DS3524, capacity of 43.2 TB, used in virtualization problems and cloud computing;
- IBM DS3512, capacity of 7.2 TB (2 pcs.), connected to the HPC cluster “Sergey Korolyov”;
- EMC CLARiiON CX300, capacity of 6.2 TB, located in the building of the science and research library;
- T-Platforms ReadyStorage SAN6998 with disk store capacity up to 112 TB, located in the science building.

To provide simultaneous high-performance file access to applications running simultaneously on several nodes in the cluster, IBM GPFS is used. The parallel file system service is organized in two disk storages IBM DS3512, two FibreChannel IBM switches and IBM x3650 M3 servers. A storage system configuration is designed to maximize the performance of read/write operations. The following results have been achieved on the basis of sample tests: the speed of consecutive file writing from one node – up to 2 Gbps, the consecutive speed of file reading from one node – up to 2.8 Gbps.

5.3. Hardware and Software System for Big Data Processing

Manufacturer: IBM.

The Hardware and Software System for structured and unstructured Big Data processing consists of two subsystems incorporated with high-performance communication media (10 Gb):

- IBM Puredata for Analytics (Netezza) – a special software and hardware complex (subsystem) for storage and analytical analysis of structured data with a capacity of fully replicated disc space of not less than 96 Tbyte (with regard to quadruple data contraction);
- IBM System X server complex for a subsystem of distributed storage and analytics processing of unstructured data using the Hadoop software technology stack (including IBM x3630 M4 control server (two Intel Xeon Processors E5-2450v2; RAM 96 Gbyte; 2 disks 600 GB each) and four IBM x3630 M4 data processing servers (two Intel Xeon E5-2450v2 Processors; RAM 96 Gbyte; 8 TB disk storage).

To provide access to the Big Data Hardware and Software System, a special classroom has been arranged equipped with 8 computers.

Fig. 8. Hardware and software system for Big Data processing.

5.4. Software

Intel© Cluster Studio XE for Linux (2014) – is a software development suite that helps achieve development, analysis and efficient optimization of HPC applications on Intel processors. It includes the following:

- C++ Compiler;
- Fortran Compiler;
- MPI Library;
- Math Kernel Library (MKL);
- Debugger;
- Trace Analyzer and Collector;
- Threading Building Blocks (Intel© TBB);
- Integrated Performance Primitives (Intel© IPP).

Intel© Parallel Studio XE Cluster Edition for Linux (2016) – is a software development suite that helps achieve development, analysis and efficient optimization of HPC applications in system clusters based on Intel processors. It includes the following:

- C/C++ compiler;
- Fortran Compiler;
- Data Analytics Acceleration library (C++, Java);
- Math library (Intel MKL) (C++, Fortran);
- TBB Threading library (C++);
- IPP Media and data library (C++);
- Intel Distribution for Python;

- Intel Advisor thread design and prototype (C++, Fortran);
- Intel Inspector memory and threading debugging (C++, Fortran);
- VTune Amplifier performance profiler (C++, Fortran, C#, Java);
- MPI library (C++, Fortran);
- ITAC MPI analyzer and profiler (C++, Fortran).

CUDA – is a parallel computing platform created by NVIDIA that allows software developers and users to boost computing performance due to use of Graphic Processing Units (GPU).

TORQUE – is a batch job processing system.

Templet Web – is a task management system used for the HPC cluster "Sergey Korolyov." The system is used for laboratory learning and research activities using the web browser. The system provides the following:

- starting of computation-intense operations in the HPC cluster "Sergey Korolyov" under the supervision of lecturers;
- in-browser program code editing;
- computing results visualization in tabular and graphical forms;
- development of computing applications using OpenMP and MPI example-based technologies;
- storage of application codes and computing results allowing for multiple-key access.

6. Master's Scientific Research

World-class academic research of the Master's program students is ensured not only by good facilities and resources, but first of all by great scientific expertise and high qualification of leading lecturers.

Over the last years, we have obtained and published results both in the field of modeling and designing of complex elements of Computer Optics and Nanophotonics [51-63] and LED structures computing [64-67], which could not be possibly obtained without using high-performance computing [68], and also in the field of construction of distributed high-performance data processing technologies using supercomputers, hybrid computing systems [17], and cloud environments [54,55] in order to conduct fundamental studies in the field of Image Processing [69-71], Geoinformatics and Nanophotonics [72], and development of new intelligent computer vision systems.

In particular, we can specify original algorithms of difference solution of wave propagation based on transition to "long" vectors, and development of a pyramid method for solving finite-difference equations of Yee schemes on GPUs [73]. The formulated numerical methods are focused on two main interdependent problems of indication of finite-difference equation solution algorithms on GPUs' architecture: full utilization of the ever-increasing number of GPU computing threads limiting the size of video RAM.

Steady interest among the Master's program students is generated by activities in the development of image analysis information technology in medical diagnostic applications [74] and operative construction technologies for digital topographical models based on radar [75-77] and aerospace data [78], development of algorithms for operative object recognition on video sequences [79-80], research in the field of Data Mining and distributed technologies for unstructured Big Data processing [81] as applied to video data stream processing [82,83], electron microscopy images [72], designing of hyperspectral equipment [84-87] for the Earth's remote sensing and relevant data processing techniques [88-90].

Using the visual (graphical-symbolic) programming technology, efficient parallel algorithms for global optimization of functions of several variables [91-92] and original methods for testing of computing software modules [93] have been developed. The Templet Web (templet.ssau.ru/app) software solution has been designed to computerize high-performance calculations [94].

The Master's degree students are provided with an opportunity to quickly and efficiently publish their results in the scientific journal "Computer Optics" [95] being issued by the scientific team headed by the Academician of the RAS V. A. Soifer [96]. According to SCOPUS, the journal "Computer Optics" is included [97] into the best dozen of journals being classified in this international bibliometric database in three main areas of journal's activities: 1) Physics, Optics (Atomic and Molecular Physics, and Optics); 2) Information Technology (Computer Science Applications); 3) Electronics (Electrical and Electronic Engineering). Besides, the Master's program students and graduates have an opportunity to submit their research results at the annual International Conference "Information Technology and Nanotechnology" (ITNT) whose proceedings are indexed in SCOPUS database. The Youth School has been organized within a framework of this Conference where the participants have the opportunity to attend lectures of leading Russian and foreign scientists.

Students for a Master's degree may participate in joint investigations conducted by the scientific school headed by the Academician V.A. Soifer in cooperation with some leading Russian and international scientific schools in High-Performance Computing. Scientists from Samara University conduct their joint research together with scientists from N.I. Lobachevskiy State University of Nizhniy Novgorod, M.V. Lomonosov Moscow State University, Ufa State Aviation Technical University [98, 99], etc. The international cooperation is carried out together with scientists from Great Britain and Germany [98], Finland [98], Uzbekistan [98], USA [89, 100], Canada, Pakistan [62], India [90], and many other countries.

Students for a Master's degree being successfully engaged in scientific research are financed from grants allocated by the Russian Science Foundation, the Russian Foundation for Basic Research, within the framework of various projects of Federal Target Programs, and economic agreements made with manufacturing enterprises and IT companies.

The Master's degree graduates may continue their studies in Samara University on postgraduate programs in the field 09.06.01 Informatics and Computer Engineering (profiles: 05.13.18 Mathematical Modeling, Numerical Computing and Software Systems; 05.13.17 Theoretical Foundations of Informatics; 05.13.01 System Analysis, Management and Information Processing; 05.13.05 Elements and Devices of Computer and Control Systems; 05.13.12 Design Automation Systems) and defend their Candidate and Doctoral Theses in respective specialties through Dissertation Councils successfully functioning in the University.

The Regulations on PhD Training have remained in force at Samara University since 2015 and it is possible to defend a PhD Thesis of Samara National Research University.

7. Conclusion

We look forward to welcoming you at the meeting at the Faculty of Information Technology of Samara University to get world-class education at the Master's program "High-Performance and Distributed Information Processing Systems".

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