Perspectives on the Emergence of Computing Programs Propelled by Local Industry in Russia

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The Republic of Karelia is a part of Northwestern Federal District of Russia. It possesses huge natural resources, extractive and processing branches of industry, and service and tourism industries that have developed intensively as well. The developing strategy of the Republic suggests a substantial development of its potential and growth of living standards for its citizens. With that aim, the region needs a modern educational environment for training highly qualified personnel in business administration systems and in information and communication technologies. The responsibility of the environment has been placed on Petrozavodsk State University—founded in 1940 as the regional multidisciplinary classical university—and playing a key role in the scientific, social and economic development of the region. This article provides a landscape of computing education from a historical perspective to the current situation with an evolving curriculum presented in some detail. Petrozavodsk State University has developed and currently maintains incubators or small "factories" where students can demonstrate useful applications of their knowledge, take part in research and development, and engage in activities leading to useful employment. This industry motivated curriculum shows a remarkable conformity with the recent CS2013 curricular guidelines.

FORMATION OF THE SCHOOL OF MATHEMATICAL MODELING

In the 1970s, Petrozavodsk State University (PetrSU) had joint Faculty of Physics & Mathematics, where two departments, mathematical analysis, and algebra and geometry, offered mathematics. During that time, the university increased its academic staff by including applied mathematicians from the established St. Petersburg State University scientific schools founded by Nobel laureate, Academician of Russian Academy of Science (RAS), Leonid Kantorovich and corresponding member of the RAS, Vladimir Zubov. Co-author Vladimir Kuznetsov was fortunate to participate in the work of the economic cybernetics department under the guidance of Kantorovich as a graduate and post-graduate student.

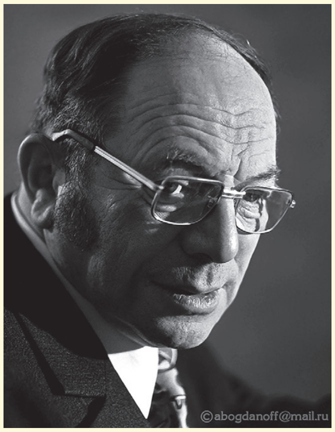


Figure 1: Vladimir Zubov

Figure 2: Leonid Kantorovich

Kantorovich contributed greatly to the application of mathematical and statistical methods in economic research [19]. After defending his doctoral thesis in 1976, Kuznetsov joined the PetrSU physics and mathematics faculty. Activities expanded in 1981 when Prof. Vladimir Chernetsky (member of the scientific school of Vladimir Zubov) moved to Petrozavodsk from St. Petersburg. Chernetsky was a known mathematician and educator; he had a creative personality, was a great organizer, and dedicated himself to the development of mathematical education and science in Karelia. In 1982, he opened the applied mathematics and cybernetics (AMC) department, initiated work on economic mathematical modeling, and made administrative agreements with industries that required performance optimization.

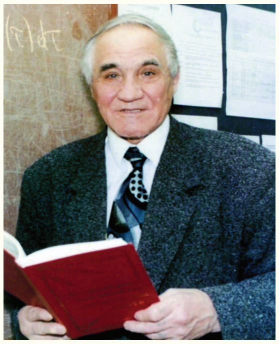


Figure 3: Vladimir Chernetsky


Figure 4: Vladimir Kuznetsov

The problems of the planning and managing of the technological processes for the pulp and paper and the timber industries are of highest priority in Karelia. The chosen science-based course—optimization models of technological processes—provided a competitive advantage for the university. As an academic organization, it was able to solve problems that were difficult if not impossible for many industrial organizations. Development and deployment began for the flagship of the Russian pulp and paper industry—the Arkhangelsk Pulp and Paper Plant (APPP)—so the plant became the main industrial partner of the AMC department for many years. Research on the problem of chemical distribution and planning of the production quantities at the APPP began in 1982. The problem formalized as a multi-periodic balanced optimization with linear restraints over a convex objective function. Later on, the AMC department formalized and solved several similar problems; for example, it solved the problem of factory balancing and production sales. Over the years, AMC formed a team of experts possessing the necessary high-level competencies. Some results of this work appear in a scientific monograph [35].

The accumulated experiences allowed PetrSU to proceed in developing integrated production control systems. Many of Kantorovich's formalizations used during the development had significant expansions. For example, the AMC department had developed industry-related systems such as a complex system for plywood production planning. Another example is a planning system for corrugated packaging production when the nomenclature of orders consisted of hundreds of titles. Nowadays, this system is available using cloud computing technology and its implementation occurs in more than twenty factories. Another example is a system for shaping raw forest materials. An advantage of the system is taking into account 3D sizes of production. The system also allows a company to plan delivery for transportation of paper rolls and cardboard by solving problems of geometrical optimization. The results on the complex factory management systems appear in a scientific monograph [36].

A team headed by Voronin and Kuznetsov developed a convenient universal library for solving linear programming problems with virtual constraints, including a selectable number of matrix columns [28,38]. It provides for increasing the speed of the development and expands the variety of the problems it solves.


Figure 5: Arkhangelsk Pulp and Paper Plant

FORMATION OF INFORMATION AND COMMUNICATION TECHNOLOGIES RESEARCH AND DEVELOPMENT

In the late 1980s, a need arose to develop the state-of-the-art processes for student training and research in the areas of networking, system programming, and software engineering. To solve this problem, Gennady Sigovtsev, who directed the course on numerical methods, took the lead of the computer science (CS) department, which separated from the AMC department in 1989. Since 2000, the head of the CS department is Iurii Bogoiavlenskii.

The work began with the development of applied software on a PC platform. In the early 1990s, the department developed and deployed a system for calculating the optimal feeding rations of fur animals for the holding company “Karelian furs” as well as a system for accounting and receiving medical patients’ statistics for the Petrozavodsk railway hospital.

Thus in the beginning of 1990s a solid foundation of scientific and human resources emerged in the field of applied mathematics, in addition to a pre-existing potential in the field of pure mathematics. This foundation allowed the FM to deploy work towards the achievement of world level curricula in the field of computing.

In 1993, the CS department entered a cooperative understanding with the department of computer science of the University of Helsinki, Finland, to carry out pilot studies in modeling and performance analysis of networking systems. In 1998, the department addressed a problem for planning the capacity of a local internet service provider [32]. Currently, research concentrates on developing an overlay test bed called “Nest” [12] providing access to the data of traffic measurements structured by spatial, organizational and hardware elements of ICT infrastructure, and their arbitrary aggregations.

The problems of modeling and performance analysis of TCP algorithms are still topical. The work on probabilistic modeling of the algorithms began in the department in 2001. Publications present semi-Markovian models of AIMD and Slow Start algorithms in presence of Bernoulli data losses [5,6]. The model yields exact numerical methods of linear complexity for calculation of distribution of the sliding window size. These works enable researchers not only to receive the estimation of average throughput but also its moments of higher degrees. Further studies [7] provide a comparison of stepwise and piecewise linear models of AIMD algorithm.

Validation of models requires data regarding TCP behavior. Utilities such as tcpdump provide insufficient and sometimes even incorrect information due to recent complications of TCP mechanisms such as implementation of TCP segmentation offloading (TSO). The description of the GetTCP system for monitoring TCP algorithms behavior at kernel level of OS Linux appears in [30]. Receiving primary data at this level provides access to the information that is absent in a user’s space.

Solutions for the problems of network management and design have a discrete nature in many situations, so using discrete models seemed justified. We started using systems of non-negative linear Diophantine equations (NLDE), the coefficients of which are arbitrary integer numbers and the solutions are non-negative integers. These systems are easy to interpret in practice; they have only one finite basis (the Hilbert’s basis) describing the set of solutions [15].

In general, the problem of calculating Hilbert’s basis is intractable. We can construct effective algorithms for its solution only for some classes of the systems. The work [8] presents further development of the approach of Portuguese mathematicians M. Filgueiras and A. Tomas; they showed how one could build and solve the non-negative linear Diophantine equation system associated with a context-free grammar. A PhD thesis by Korzun [21] showed the construction of new classes of associated systems and developed pseudo polynomial syntactical algorithms for calculating Hilbert’s

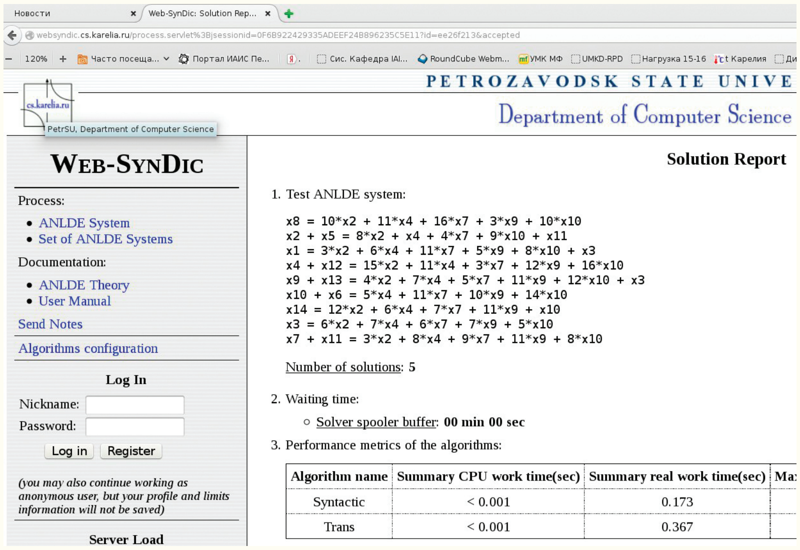
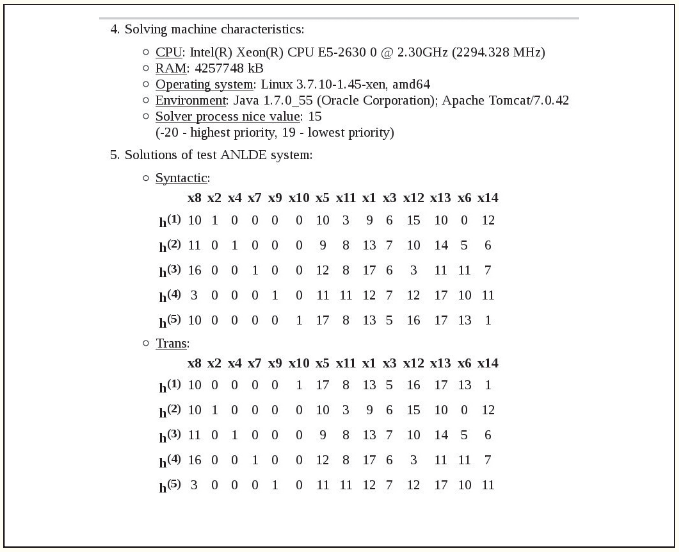


Figure 6: WebSynDic screenshot 1: An NLDE system.


4. Solving machine characteristics:

- CPU: Intel(R) Xeon(R) CPU E5-2630 0 @ 2.30GHz (2294.328 MHz)
- RAM: 4257748 kB
- Operating system: Linux 3.7.10-1.45-xen, amd64
- Environment: Java 1.7.0_55 (Oracle Corporation); Apache Tomcat/7.0.42
- Solver process nice value: 15 (-20 - highest priority, 19 - lowest priority)

5. Solutions of test ANLDE system:

- Syntactic:

	x8	x2	x4	x7	x9	x10	x5	x11	x1	x3	x12	x13	x6	x14
$h^{(1)}$	10	1	0	0	0	0	10	3	9	6	15	10	0	12
$h^{(2)}$	11	0	1	0	0	0	9	8	13	7	10	14	5	6
$h^{(3)}$	16	0	0	1	0	0	12	8	17	6	3	11	11	7
$h^{(4)}$	3	0	0	0	1	0	11	11	12	7	12	17	10	11
$h^{(5)}$	10	0	0	0	0	1	17	8	13	5	16	17	13	1

- Trans:

	x8	x2	x4	x7	x9	x10	x5	x11	x1	x3	x12	x13	x6	x14
$h^{(1)}$	10	0	0	0	0	1	17	8	13	5	16	17	13	1
$h^{(2)}$	10	1	0	0	0	0	10	3	9	6	15	10	0	12
$h^{(3)}$	11	0	1	0	0	0	9	8	13	7	10	14	5	6
$h^{(4)}$	16	0	0	1	0	0	12	8	17	6	3	11	11	7
$h^{(5)}$	3	0	0	0	1	0	11	11	12	7	12	17	10	11

Figure 7: WebSynDic screenshot 2: Solution of the NLDE system from screenshot 1.

basis. Successive elimination (Gauss type) method for computing the Hilbert basis and for generation of NLDE systems with a known basis is developed in the doctoral thesis by Kulakov [27]. These two algorithms were implemented in the software system WebSynDic [10,40], enabling one to define and solve NLDE systems using a web interface. The studies of Diophantine modeling continue and a summary appears in a monograph [24].

CURRICULA FORMATION: IT SPECIALIST EDUCATION BASED ON APPLIED MATHEMATICS AND COMPUTER SCIENCE

The AMC department continuously has been improving the teaching process. In 1984, Prof. Chernetsky opened the "Applied Mathematics" specialization of studies. Such basic courses as 'Optimization Methods,' 'Combinatorial Algorithms,' 'Operations Research,' and others became a part of the teaching process. In 1986, the faculty of mathematics (FM) separated from the physics and mathematics faculty and created a postgraduate program and a council for awarding the PhD degrees. For instance, the current PetrSU rector, Prof. Anatoly Voronin, was the first postgraduate student of Prof. Chernetsky in Petrozavodsk; in 1993, Anatoly Voronin became the head of the AMC department.

Figure 8: Anatoly Voronin

Thus in the beginning of 1990s a solid foundation of scientific and human resources emerged in the field of applied mathematics, in addition to a pre-existing potential in the field of pure mathematics. This foundation allowed the FM to deploy work towards the achievement of world level curricula in the field of computing.

In the Former Soviet Union, five-year programs with the release of the so-called diploma specialists conducted higher education studies. The content of training was determined by centralized state educational standards (SES) in areas called specialties (professions). The standards were developed by groups of experts commissioned by the Ministry of Education and contained a list of courses compulsory for all higher education institutions, and, to a minor extent, regional and institutional components.

Historically, radio engineers developed hardware of early computers but mathematicians have played a huge role in the development of computing in the former Soviet Union. Development of system and application software was implemented, to a large extent, by graduates of specialty 'mathematics' of classical universities, who took specialized training in applied mathematics and computing. Even a title of the new specialty for educating students on hardware design opened in the mid-1950s sounded as 'mathematical counting and solving appliances and devices.' Just ten years later, they renamed it 'electronic computational machines.'

Information regarding the contemporary world level of computing and the corresponding education has become more available since the mid-1980s with the development of the "perestroika" process. The penetration of personal computers, OS Unix, modern DBMS, and other advanced hardware and software tools and technologies began to develop in the former Soviet Union and then in Russia. They gradually introduced the tools and technologies into industry, governmental and educational institutions, and other spheres of society. The need for specialists capable of using these innovations professionally had appeared. Classical and technical universities of Russia actively studied these tools and technologies. Universities were keenly aware of the need to accelerate the coordination of developing the computing curricula process with global trends.

In 1991, employees of the faculty of mathematics of PetrSU had reviewed the approach for teaching computing as per "Computing Curricula 1991" (also known as CC'91) [31] developed by ACM and IEEE-CS. The definition of computing as a discipline in CC'91, which used three working paradigms and contained one optional and ten required subject areas, became an obvious step forward in understanding the nature of the discipline. CC'91 presented curricular recommendations for baccalaureate programs that allowed the development of curricula on the regular basis.

At this time, SES "mathematics" conducted graduate education at the FM with two tracks—'enterprise employee' and 'teacher.' Students enrolled in several computing courses such as programming in FORTRAN with laboratory work carried out in interactive classes on Soviet clones of the IBM 360 and the PDP-11.

In late 1991, a working group, under the leadership of FM dean Andrey Pechnikov, considered the modification of the curriculum taking into account the recommendations of CC'91. The updated curriculum had to provide training of specialists at the world level for the needs of the faculty and for the needs that existed in society. One more requirement was to keep the existing advantage of the high mathematical skills of the faculty.

Activities of CC'91 had as its foundation the idea formulated in CC'91 that stated that "Computing sits at the crossroads among the central processes of applied mathematics, science, and engineering." Therefore, the working group concentrated on including in the curriculum elements supporting the "design" paradigm that included "theory (mathematics)" and "abstraction (modeling)" that already existed in the existing curriculum. CC'91 also stated that "in computing the three processes are so intricately intertwined." Therefore, the task of the working group was "to weave" the design paradigm (mathematics, science, engineering). It became possible to realize that updating a curriculum using the recommendations of CC'91 were 'intentionally flexible.' Generally, the updated curriculum was not simply direct instantiations of the ACM guidelines but a combination of existing mathematical ones using the ideas of CC'91.

In 1992 the Ministry of Education of Russia approved the four-year bachelor SES in the direction of applied mathematics and computer science (AMCS) that provided to the universities considerably more freedom in designing a curriculum. This officially allowed the FM, one of the first in Russia, to open the admission of students in the fall of 1993 to this direction of education on a modified curriculum. In 1997, it started a master's program in the same area.

The AMCS curriculum contained essentially fewer mathematical courses although there were enough of them not only to cover the mathematical requirements of CC'91 but also to develop students' complete mathematical background. Also retained were the block of science courses, for example physics. Table 1 presents the courses that the FM has added to the curriculum because of the recommendations of CC'91. The column "Total Hours" indicates the sum of hours for lectures, laboratories and/or practicums, self-instruction, and examinations.

TABLE 1.
CS COURSES OF PETRSU AMCS CURRICULUM 1993-1994

Title	Total Hours		Total Hours
Introduction to Computing	408	Operating Systems	153
Algorithms and Data Structures	408	Formal Languages	102
DB design	153	Compilers Design	102
Software Technology	153	Artificial Intelligence	102
Computer Organization	102	Computer Graphics	102
Elective Courses	340		

The new curriculum covered the CC'91 'Core of Knowledge Units,' although the details of the coverage at that time were not analyzed; we made this analysis later in the article by Bogoiavlenskii [11]. The shortage of teachers was a major limiting factor initially. We overcame this limitation by an intensive development of new courses by young teachers who graduated from St. Petersburg State University as well as through the involvement of teachers from the Karelian research center of the RAS, from the computing center of PetrSU, and from other organizations. Laboratory work occurred in computer classrooms equipped with a sufficient number of PCs. There was no shortage of books since at that time translations of literature were already available in Russian.

A few years later, the AMCS direction became very popular among the students, which turned into an educational brand of PetrSU. Its graduates are still in great demand by employers. Many of them have defended their doctoral dissertations and now hold teaching and research positions at the FM.

The FM soon opened new directions of study in "Information Systems and Technologies" (1999) and "Business Informatics" (2006). Nowadays, more than five hundred students take part in these three directions of study. The most talented graduates continue studying at postgraduate educational programs and at higher doctorate programs; they defend their dissertations at PetrSU and at St. Petersburg State University councils.

An important role in specialist training was the programmer's creativity club organized by Kuznetsov. Since 2000, more than a hundred pupils and students are studying mathematical modeling, optimization, algorithm theory, and programming, and are participating in the city and republic academic programming contests. The club's teams successfully take part in the ACM international collegiate programming contests. The teams won two bronze medals (2007 and 2008) and one silver medal (2010). For more than ten years, PetrSU has been organizing summer and winter international training contests where more than forty Russian teams and some of the world's strongest teams take part.

Figure 9: Silver medalists of ACM ICPC 2010. Left to right: Aleksei Nikolaevski, Denis Vlasov (Vice-Coach), Denis Denisov, Ilia Nikolaevsiki

The AMC and CS departments did a serious job in training students in team software development. The CS department in 2004 implemented a preparatory software project by developing a prototype of the system WebSynDic [10,40]. As a next step, in the spring of 2005, a team of five Russian and six Finnish students in a remote mode of interaction developed the software project DaCoPAn [33]. The system of training in software engineering includes the following stages:

1. Programmers creativity club
2. Basic training in small teams to develop programming skills
3. Study skills in team development projects by developing a style close to real industrial conditions
4. Students engage real industrial projects in departments and in the IT-Park of PetrSU (see below).

The training process uses software tools based on OS Linux implementing in the paradigm of free and open-source software (FOSS). The software currently controls a wide variety of hardware architectures. Anticipating this development, the CS department organized mastering and use of OS Linux since 1993. Our first distribution of Slackware (on one hundred 3.5-inch floppy disks!) was due to the courtesy of our partner, Prof. Martti Penttonen, head of the computer science department at the University of Joensuu, Finland.

The commissioning of OS Linux forced the CS department faculty and staff members to make significant efforts. Since 1994, they have actively studied Linux and its tools and developed software solutions for scientific and educational purposes in this environment. Since 2000, laboratory software for introductory courses ran on a single server supported by CS department staff. Students used the utility `putty` to access the server from Windows classes first in a text, and later in graphics mode using an Xming server. They also used the C language and the gcc compiler for introductory programming courses. The department also prepared and published textbooks on the C language as well as bison and flex tools. (Currently, Russia has published many translated and native textbooks.) Generally, we use all the classic tools of the OS. In

2008, we installed the OpenSUSE distribution of Linux for two computer classes.

The computing system [13] based on the OpenSUSE distribution now satisfies the needs of students and staff. The system has powerful servers and other necessary hardware. OS Windows is also widely used; all workstations are dual-bootable. Ideas and tools of the FOSS and of the proprietary environments are practically identical in many cases. Our experience [9,37] shows that the reliance on the FOSS in the teaching process significantly expands the horizons of knowledge and skills of students, and does not restrict their ability to work fluently in proprietary environments.

The FM is constantly modifying the curriculum in line with the development of the discipline. For example in 2005, after the emergence of CC2001 [2], the curriculum for the first four terms was as follows (table is from [11]).

TABLE 2.
FRAGMENT OF PETRSU AMCS CURRICULUM 2005-2006

1st term	CTC	2nd term	CTC
Introduction to ICT	0.5	Shell Language	0.5
Introduction to Processors (Assembly Language)	0.5	Introduction to Processors (Assembly Language)	0.5
Programming and Algorithms (C Language)	1	Data Structures	1
Discrete Mathematics	1	Mathematical Logic	0.75

3rd term	CTC	4th term	CTC
Combinatorial Algorithms	1	Combinatorial Algorithms	1
Data Bases	1	Operating Systems	0.75
Computer Networks	0.75	OOP in .NET Environment	0.75
OOP in Java Environment	0.75		

In the table, one CTC stands for conditional term course corresponding approximately to 2 lecture hours plus 2 hours of practical training plus 2.12 hours of self-instruction per week during the 16.5 weeks for one term.

In 2006, based on the ideas of Overview Report [17], we conducted comparative research [11] on study hours provided by the core 'Bodies of Knowledge' for computer science [2], information systems [1], information technology [3], and software engineering [18] disciplines concerning our own CS body of knowledge core. The 2001 the computer science body of knowledge contained fourteen knowledge areas. Accomplished temporal characteristics and comparative analysis showed that these core areas are entirely contained in the study hours of SES AMCS program provided for computing studies.

Bogoiavlenskii offered [11] a "reverse approach" to curricular guidelines development by introducing corresponding engineering components in a curriculum that provided intensified mathematical training. In the SES AMCS program, there is enough time for special and elective courses, which makes it rather flexible to accommodate fast changes in the computing area.

Computer Science Curricula 2013 (CS2013) contains eighteen knowledge areas with the core subdivided into "Tier-1" and "Tier-2" components. This partition complicates curricular development when covering all mandatory requirements. Currently, the FM is in the process of doing a gradual approximation to them. The current version of the curriculum appears in the Table 3 that contains course blocks HU/SS (humanitarian or social sciences), Math (mathematical), CS-nn (computer science), and ApMath (applied mathematical). In general, courses are compulsory and some courses can last for several terms. We use the two-term system. The designation CS-nn-O means that a student may not take the course when we group elective courses in pairs. A student must take one course from each pair. We do not show the fourth-year of the curriculum because almost all courses there are elective and they do not associate with the CS2013 core directly. (OOP stands for object-oriented programming; CLI stands for command line interface.) Hours are the equivalent of lecture hours.

We have analyzed the degree of compliance of this curriculum with recommendations of CS2013 by considering the content of the twelve compulsory CS courses. The results appear in Table 4. Column M denotes mathematical and applied mathematical courses. We viewed Tier-1 and Tier-2 recommendations as a whole.

The AMCS curriculum covers a total of 223 hours from Tier-1 and Tier-2 308 hours. So, the average of the total coverage is 72.4%. Coverage for CN, DS, SDF, IM, SE, AL, and PL areas fall within the 84% - 100% range. Coverage for AR, NC, GV, and OS areas is very reasonable in the 67% - 75% range. The lower coverage for areas PD, HCI, IAS, and IS fall within the 40% - 57% range; this is due to the fact that the PD area is now additionally covered at the master's level as is the SF area due to corresponding SES. The IS area is not of high importance in the region. The department plans to have greater exposure to the HCI and IAS areas in the near future. Students cover professional practice and other general issues of the SP area in HU/SS block; we also require these of students so they understand issues in the computing context. Generally, we plan to make the curriculum closer to CS2013 requirements.

PetrSU is actively developing curricula that allow training of specialists at the modern level in the rapidly developing areas of computing. We utilize the experience and approaches from the international community and from ACM and IEEE-CS curricular recommendations. Realizing the rapid expansion of this field, the council of the mathematical faculty has recently decided to rename itself the Faculty of Mathematics and Information Technologies.

INTERNATIONAL COOPERATION

Since 1994, the AMC department with support of the Finnish company Valmet Automation (now called Metso Automation) held an annual international conference titled, "New information technologies in pulp and paper industry." The event brought together representatives from the largest companies in the industry, the most important industry-specific R&D organizations, as well as a number of universities of Russia and Finland.

Cooperation with the computer science department at the University of Helsinki since 1993 in the form of mutual research and

TABLE 3. CURRENT PETRSU BACHELOR DEGREE "APPLIED MATHEMATICS AND COMPUTER SCIENCE" CURRICULUM

Block	Course title		Hours
	Year I, Term 1		
HU/SS	History, Foreign Language		90
Math	Mathematical Analysis, Algebra, Analytic Geometry, Discrete Mathematics		165
CS-1	Programming: Introduction, C Language		30
	Year I, Term 2		
HU/SS	Foreign Language		60
Math	Mathematical Analysis		60
CS-2	Computer Organization: Introduction		30
CS-3	Algorithms and Data Structures: Introduction		30
CS-4	Human-Computer Interface		15
CS-1	Programming: OOP, C# Language		30
CS-1	Programming: CLI shell		15
	Year II, Term 3		
HU/SS	Foreign Language		60
Science	Physics		15
Math	Real analysis, Differential equations		75
CS-5	Computer graphics		15
CS-1	Programming: Java Platform		30
CS-6	Operating Systems		30
CS-3	Algorithms and Data Structures-1		30
CS-1	Programming: the UNIX Environment		15
	Year II, Term 4		
HU/SS	Foreign Language, Elective course		90
Math	Functional Analysis, Probability Theory and Mathematical Statistics, Differential equations		90
Science	Physics		15
CS-7	Data Bases		30
CS-3	Algorithms and Data Structures-2		30
CS-8	Computer Networks		30
CS1-O	Programming: Cross Platform Development		30
	Year R&D Project		
	Year III, Term 5		
HU/SS	Foreign language: Professional communication		30
Math	Complex analysis, Probability Theory and Mathematical Statistics		60
ApMath	Optimization Methods		30
ApMath	Elective	Computational Aspects of Combinatorics	45
ApMath	Elective	Introduction to the Mathematical Modeling of Social and Economic Systems	
ApMath	Elective	Combinatorial Algorithms of Exponential Complexity	30
CS-9	Elective	Software Engineering: Development Tools	
CS-10	Web Technology-1		15
CS-11	Parallel Computations		30
CS-9	Software Engineering: Process		30
	Year III, Term 6		
HU/SS	Foreign language: Professional communication		30
Math	Mathematical Logic, Numerical methods		75
ApMath	Operations research		30
CS-12	Elective	Game Theory	30
CS-12	Elective	Formal Languages and Compilers	
CS-11	Web Technology-2		30
CS-9	Software Engineering: Team Project		30
CS-2-O	Computer Organization: Advanced topics		30
CS-9-O	Software Engineering: Mobile Devices Platforms		30
	Year R&D Project		

TABLE 4.
COMPLIANCE OF CC2013 BODY OF KNOWLEDGE CORE WITH AMCS CURRICULUM 2014-2015.

CS2013 Knowledge Areas	Number of a CS Course from the Table 3													Estimate Percent Compliance
	1	2	3	4	5	6	7	8	9	10	11	12	M	
	Hours													
AL-Algorithms and Complexity	1		18									3	2	86%
AR-Architecture and Organization		12												75%
CN-Computational Science													1	100%
DS-Discrete Structures													41	100%
GV-Graphics and Visualization					2									67%
HCI-Human-Computer Interaction				4										50%
IAS-Information Assurance and Security	1					1		2						44%
IM-Information Management							8			1				90%
IS-Intelligent Systems			4											40%
	Number of CS Course from the Table 1													
	1	2	3	4	5	6	7	8	9	10	11	12	M	
	Hours													
NC-Networking and Communication								7.5						75%
OS-Operating Systems						10								67%
PBD-Platform-based Development	5		1	5	2	6	2			15				N/A
PD-Parallel and Distributed Computing											8.5			57%
PL-Programming Languages	17											4		84%
SDF-Software Development Fundamentals	18		11							9		2		93%
SE-Software Engineering									24					88%
SF-Systems Fundamentals	1			1		2		1		1	1			26%
SP-Social Issues and Professional Practice	1	1					1		1					25%

study visits of lecturers and students has been an ongoing partnership. Since 1997, the computer science department in Petrozavodsk has organized an annual international workshop entitled "Advances in methods of information and communication technology" (AMICT) where students and young scientists present their R&D work [4]. We have published eleven volumes of the proceedings from this workshop. Associate Professor Dmitry G. Korzun also conducts joint research with colleagues from Helsinki information technology institute.

In 2008 PetrSU entered the Open Innovation Association FRUCT (Finnish-Russian University Cooperation in Telecommunications) [14], focusing on arranging an international group of students supervised by creditable experts who would push forward R&D work related to advanced information technologies. Drawing on the experience of using Linux and modern systems of training in the discipline of software engineering, the CS department began the FRUCT initiative by developing applications for Nokia Corporation mobile devices N800, N810, N900 using Linux-like OS Maemo and Harmattan. Nokia supported this work.

In 2011, PetrSU together with FRUCT won contests supported by the Karelia European Neighborhood and Partnership Instrument, Cross-border Cooperation (ENPI CBC) program [20] and received three project grants for period 2011-2014 totaling more than 1,200,000 Euros. The European Union, the Republic of Finland, and the Russian Federation funded the program. Staff and students of the CS department and IT-Park of PetrSU carried out the grants.

The aim of the first project (Complex Development of Regional Cooperation in the Field of Open ICT Innovations) was the formation of a local team that was able to develop applications to meet the requirements of online stores. More than twenty applications [29] for Symbian, Maemo, Harmattan, Android, and Windows phone operating systems were uploaded in online stores of corresponding companies and were downloaded by users several hundred thousand times. Also R&D was carried out within the directions of Smart Spaces and Internet of Things [22,23,26] in frame of this project. In 2015, on the basis of the R&D results [25], the CS department and IT-Park won in contests announced by the Russian Foundation for Basic Research and by the Ministry of Education and Science of the Russian Federation. Two other ENPI projects aimed at developing mobile applications for tourists and people with disabilities. They also concluded successfully.

Figure10: Students and teachers of Five weeks Summer Practice 2009 on developing mobile applications. In the foreground Dmitry Korzun (left) and Iurii Bogoiavlenskii.

Figure11: Managers and created team of young developers. Left to right. Sitting: Iurii Bogoiavlenskii, Anton Shabaev, Anatoly Voronin, Sergei Balandin, Dmitry Korzun, Standing: 1st row: Diana Zatseva, Eugen Tsvetkov, Andrei Bogachev, Kirill Kulakov, Aleksandra Reiss, Dmitry Kositsyn, 2nd row: Stanislav Epiphanov, Igor Burlak, Aleksandr Lomov, Kirill Ivashov, Ingmar Bergman, Andrei Megenin, Sergei Zaharov, Aleksandr Sannikov.

International cooperation has significantly contributed in the modernization of students' education quality and in educating a new generation of teachers and researchers who are able to conduct R&D at a modern level.

PETRSU INNOVATIVE STRUCTURE

The establishment of IT-Park in 2005 has provided qualitative breakthrough in the development of innovative activities of PetrSU. After renovation, we equipped the building of more than 4000 square meters with more than two hundred workstations and other research equipment for students, postgraduates, instructors, and staff who specialized in mathematical modeling, information and nanotechnologies, and microelectronics. The facility also houses the programmer's creativity club, the student business incubator, and the PetrSU directorate for innovation and production.

The subdivisions of IT-Park carry out orders from leading Russian and foreign companies and organizations. The subdivisions also actively participate in the project and grant programs. Factories of forestry, pulp and paper, engineering and petrochemical industries of Russia, and world innovation leaders such as Nokia, Samsung, Metso Automation, Metso Minerals, and Outotec are among the partners and customers of the IT-Park.

Because of IT-Park, twenty-four small innovative enterprises began since 2010, executing orders for hundreds of millions of rubles. Nowadays, IT-Park is actively implementing previously completed works and carrying out advanced optimization R&D. The accumulated experience coupled with the human and scientific potential have allowed IT-Park to open new directions such as developing a system for planning and factory management based on cloud SaaS technology [39].

CONCLUSION

We have just reviewed the evolution of a computing curriculum at Petrozavodsk State University. From its beginnings in the 1970s and the 1980s, we saw that computing curriculum responded to a need by local and regional industry to transform itself from mathematically-oriented curriculum to an industry-oriented one. Industry involvement motivated much R&D and caused the creation of IT incubators and research parks. We also have shown that the curriculum today is in harmony with the recent ACM/IEEE-CS curricula recommendations for computer science known as CS2013. In fact, the PetrSU curriculum and the recommendations are similar with about 72% compliance. We find this situation remarkable, given the independence of the two activities. Over the next few years, we expect greater agreement as the program continues to evolve.

Activities of AMC and Finnish computer science departments continue. The PetrSU IT-Park has provided dynamic development trends of economic and mathematical modeling, optimization methods, and applications of modern ICT. PetrSU created the faculty of mathematics and formed scientific and pedagogical schools that educate highly qualified personnel through industry demand from the Republic of Karelia and beyond. The faculty team was able to formulate a wide range of practically important and theoretically interesting problems, to implement a variety of management systems of technological processes and enterprises, and to organize the development of software systems and mobile applications based on industrial methods of software engineering. Today, a robust group of professors and lecturers exist at the AMC and CS departments who are preparing a younger generation of lecturers and researchers. Almost all lecturers have defended their PhD theses. Almost all the faculty members participate in projects and contract work.

Figure12: Master's graduates in 2011 and Iurii Bogoiavlenskii

The teaching process of the faculty of mathematics is fully consistent with modern global trends, planned and developed in close contact with international [16,34] and Russian educational communities because of our own experience of the concept of the 'reverse approach.' PetrSU IT-Park is a modern technological platform for educating students with enlightenment and enthusiasm, and with the awareness of the social importance of their profession to humanity. **Ir**

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