Russian-Dutch double-degree Master’s programme in computational science in the age of global education

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\section*{Abstract}

We present a new double-degree graduate (Master’s) programme developed together by the ITMO University, Russia and University of Amsterdam, The Netherlands. First, we look into the global aspects of integration of different educational systems and list some funding opportunities. Then, we describe our double-degree program curriculum, suggest the timeline of enrollment and studies, and give some examples of student research topics. Finally, we discuss the issues of joint programs with Russia and suggest possible solutions, analyze the results of the first three student intakes and reflect on the lessons learnt, and share our thoughts and experiences that could be of interest to the international community. We will look into the global aspects of integration of different educational systems and list some funding opportunities. Then, we describe our double-degree program curriculum, suggest the timeline of enrollment and studies, and give some examples of student research topics. Finally, we discuss the issues of joint programs with Russia and suggest possible solutions, analyze the results of the first three student intakes and reflect on the lessons learnt, and share our thoughts and experiences that could be of interest to the international community.

1. Introduction: Why computational science? Why now?

In the past decade, computational science has become an indispensable tool in all fields of human life: from traditional physics and engineering to biology, medicine, economics, arts, sociology and more exotic fields like fashion or criminology. The world turns progressively more digitized and interconnected, with smartphones and smart homes continuously computing something for us, smart systems controlling transportation and production, and early warning and decision support systems protecting our safety and well-being.

Progress in these smart technologies requires a growing pool of new-wave professionals who can develop models, algorithms and software tools, and then efficiently harness computational resources available in a multitude of hardware and middleware environments (from smartphones and laptops to high-performance clusters, supercomputers, Grids and Clouds). Experts in computational science are highly valued in all research institutions and industrial sectors, but until recently only few universities provided complete coherent educational programmes in computational science, e.g.\textsuperscript{[1–3]}

The University of Amsterdam pioneered this field by establishing the Computational Science group\textsuperscript{[4]} in 1990 and a Master’s program\textsuperscript{[3]} in 2005, first as a track in Computer Science and Grid Computing programs. The computational science group led by Prof. Peter Sloot has been collaborating with several Russian research institutes within international projects. These strong ties resulted in a special award from the Russian government for setting up an Advanced Computing Lab\textsuperscript{[5]} at the ITMO University, St. Petersburg, within the Leading Scientist Programme\textsuperscript{[6]}. One of the goals of this program was the development of joint educational and research programs\textsuperscript{[7]}.

A great initiative taken by the organizers of the Workshop on Teaching Computational Science\textsuperscript{[8]}, held in conjunction with the International Conference on Computational Science\textsuperscript{[9]}, brings together researchers and educators to push forward this challenging and exciting branch of science. Joint efforts and strong
incentives from high-tech industries helped to promptly establish several new educational programmes in computational science around the world [2], [10], but the curricula and educational methods were often inherited from the existing programmes in computer science and applied mathematics and physics. Establishing an internationally recognized benchmark in computational science curriculum could be one of the goals in this workshop.

This is an extended version of a conference paper [11] invited to the special issue of the Journal of Computational Science. In this paper, we present a new double-degree Master’s programme developed together by the ITMO University, Russia and University of Amsterdam, The Netherlands. First, we look into the global aspects of integration of different educational systems and list some funding opportunities from European foundations (Chapter 2). Then we describe our double-degree program curriculum, suggest the timeline of enrollment and studies, and give some examples of student research topics (Chapter 3). This information may be useful to the prospective students. Finally, we discuss the issues of joint programs with Russia and suggest possible solutions, analyze the results of the first three student intakes and reflect on the lessons learnt, and share our thoughts and experiences that could be of interest to the international community expanding the educational markets to the vast countries like Russia, China or India (Chapter 4).

2. Global integration of educational systems: Why and How?

2.1. Past, present and future of global education

Globalization and amalgamation of world economies, with strong interdependencies between the countries, have led to gradual integration of the educational systems. The first wave came with the Age of Enlightenment in 17–18th centuries, which defined the school of thought in Western Europe 1 and spread out to Southern and Eastern Europe, Russia, European colonies in Africa, Asia and America. In the next two centuries, the educational systems developed consistent and compatible programs for primary and secondary education, and started to form the basis of a global higher education. Alas, the two World Wars and the Cold War of the 20th century disrupted the integration process and essentially separated the educational systems of the Western Bloc and the Eastern Bloc. The only positive side of this separation was the extreme competition that boosted higher education (although largely inclined towards the military-driven engineering).

Only the last years of the 20th century resumed the integration process by the Lisbon Recognition Convention 2 (1997) and the Bologna Process (1999), which created the European Research Area (2000) and European Higher Education Area (2010) 3. With these new rules and standards, joint-degree and double-degree programs are becoming very popular in higher education. The universities benefit from this model because they can introduce new educational programmes without hiring extra staff, instead offering some courses in partner-universities. The students find it very attractive because they can learn from the best teachers in the field and gain a unique international experience while studying in different countries. Recognizing these benefits, European foundations offer a variety of granting opportunities through Tempus 4, Marie Curie 5, Erasmus and Erasmus Mundus programme 6. A review of the progress made in international student mobility can be found in [12].

2.2. Focus on Russia and BRICS: Why is EU & USA interested?

All successfully developing countries (e.g., BRICS countries) reach a point when they need to adopt the top technologies to progress further. That requires more than just a few highly skilled experts imported from the technologically developed countries: it requires mass education. In the past decade, China and Russia have entered this phase; now India and Brazil are joining the race. At the same time, Western Europe is aging and outsourcing most industries to other countries, instead concentrating on banking, management and research. These two factors shrink the supply of local students enrolled in the hard-science (STEM) programs.

This is a happy point where the demand for top-quality education in developing countries meets the supply of professors and educational programs in the developed world. China was only partly successful in sending their students to top universities (mostly in the United States), under the condition that they come back to work in China: most students did not return. Of course, the high-tech companies where they land are happy with this fact, but for the Chinese government this method is questionable 7. Another way to make both parties satisfied is establishing joint educational programs. This is the way we are exploring in the University of Amsterdam, the Netherlands and ITMO University, Russia.

Russian education has been traditionally very strong in hard sciences: mathematics, physics, chemistry, engineering, and informatics. This important tradition from the Soviet times comes together with the highest in the world ratio of highly educated people: 54% of the Russian labor force has attained a tertiary (college) education, according to a 2008 World Bank statistic http://goo.gl/1KcMUL. With this excellent background and a tradition of working hard, 8 Russian students are well prepared to take even the most challenging courses in top world universities, that is, if they manage to learn the foreign language (more on that in Section 2.3).

In 2012, Russia decided to promote 15 Russian universities to the TOP-200, out of which 5 universities should land in the TOP-100 of the world’s leading universities according to the QS World

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1 Curiously British coffeehouses (not to be confused with the modern Dutch coffeeshops for smoking marijuana) played a crucial role in scientific exchange and educational reform discussions.
2 Lisbon Convention on the Recognition of Qualifications concerning Higher Education in the European Region is an international convention of the Council of Europe elaborated together with the UNESCO, ratified by all 47 member states of the Council of Europe. It was also signed by Canada and United States, but not ratified yet.
3 The Bologna Process strengthened the competitiveness of the European higher education and fostered student mobility and employability. It includes all 47 member states of the Council of Europe. The European Higher Education Area was created to ensure more comparable, compatible and coherent systems of higher education in Europe http://www.EHEA.info.
4 Tempus (Trans-European Mobility Programme for University Studies) is the European Union’s programme which supports the modernisation of higher education in the Partner Countries of Eastern Europe, Central Asia, the Western Balkans and the Mediterranean region, mainly through university cooperation projects http://eacea.ec.europa.eu/tempus/.
5 Marie Curie Fellowships are European research grants available to researchers regardless of their nationality or field of research. Scientists have the possibility to complete their training with competences or disciplines useful for their careers. http://ec.europa.eu/research/mariecurieactions/.
7 As we were finishing this paper, Russian government declared a similar program, fully covering education of 3000 Russian students in top 200 universities http://en.r-itar-tass.com/opinions/1643 under the condition of coming back to work in Russia. There is one important question though: Does this project still make sense if very few students actually return? Chinese experience shows that the imposed fine cannot solve the problem.
8 Russian high schools and most universities had a workload of 40 contact hours per week in the class plus up to 20h homework per week. This load is now reducing, after Russia joined the Bologna Process limiting the program workload.
University Rankings by 2020. This Program, conveniently called 5–100–2020, has a budget of over 40 billion rubles (over 1 billion Euro or 1.4 billion US dollars) for the first 3 years (till 2016). Without discussing the pros [13] and cons [14] of this urgent desire to be in the international ranking [15], the top 15 Russian universities, including the ITMO University, have already received the money and are eager to invest in academic mobility and scientific cooperation with the TOP-500 world universities. Joint research projects and educational programs are extremely important in this race, therefore, the number of such programs will grow exponentially in the very near future.

2.3. Integration with Russia: Global issues and solutions

We see 4 global issues that may hamper a quick progress in the ranking race: (1) separation of Russian educational system from research institutes; (2) cultural differences; (3) language issues; and (4) partial incompatibility of Russian educational system with the majority of the leading world universities, including those in EU. Some of these difficulties were also mentioned by an international consortium developing a European–Russian–Central Asian network of Master’s degree in Informatics [16].

A few words about each issue and possible solutions:

(1) Russian higher education is traditionally run by the universities under the Ministry of Education, whereas research institutes are run by the Russian Academy of Science. They are disconnected. Some collaboration and a few academicians and researchers teaching in educational institutions only slightly alleviate the problem. This is a fundamental issue that requires a strong political decision and immense wisdom in its implementation. Last year the first steps have been taken in transforming the Academy; that stirred a wave of protests. We can only hope that the merger of education with research will bring more benefits than losses.

(2) The cultural differences are acutely experienced by the students and coordinators of joint Master’s programs. Russian education has been traditionally more rigid, with teachers and supervisors giving precise instructions and requiring exact execution. Combined with the high workload (both in class and at home), this approach gave students very strong qualifications in the subjects they learnt, but as a result students often lack the skills of self-learning and innovative thinking. In recent years, new young teachers appeared in universities, often with some research background. They will gradually transform the old stiff approach into a more open-minded style practiced in European Union and in the United States, where students are expected to show initiative and work on their own. Changing the Russian style will take another half-generation because it would be disrupting to dismiss the old professors with a valuable knowledge and teaching experience. As a short-term solution, we can only tell students about these cultural differences and instruct them not to wait for instructions in European universities, to enjoy the freedom in selecting research topics and optional courses, and to find their own ways in solving problems.

(3) Most EU countries have launched international Master’s programs in English, and most Russian schools are teaching English starting from the secondary education (or primary education in specialized schools), and most Russian universities offer weekly English lessons in the first 2 years of Bachelor programs. But in spite of this, the situation with the language is not as cloudless as we would like it to be. There are two reasons for this: First, the Russian language is very far from the English\(^5\); and second, Russia has been largely isolated from Western Europe for several generations (roughly, from the Russian revolution in 1917 till the fall of the Soviet Union in 1991 and several years of chaos that ensued). This unfortunate combination explains why even after a decade of somewhat open international relations and modernization of Russian education, the English language is still a challenge most of the students are facing—often without even knowing it until they take the TOEFL or IELTS test. Our experience shows that most students enrolled in our Master’s program are good in reading, about a half can decently write, but only 10% score high in listening and speaking tests.

The only global solution to this problem would be introducing the English lessons earlier (in primary school or even kinder garden) and increasing the professional level of teachers. Obviously, this will take a long time and lots of efforts on all levels, from government to schools and parents. The short-term solutions for the joint Master’s programs could be either introducing intensive language courses, preferably starting on a Bachelor level, or adding an entry requirement of TOEFL or IELTS score only slightly below than that required by the partner-university in EU or USA.

(4) Until recently, the Russian higher education system was incompatible with the Bologna Process: the lowest degree in Russian universities was the Specialist, obtained after 5–6 years of studies. Only in October 2007, Russia enacted a move to the two-tier education model in line with Bologna Process. Transition to real Master’s degree was completed in 2014. The labor market in Russia still regards BSc diplomas as inferior to classic Specialist education, thus MSc stage remains mandatory for most graduates. This is a disadvantage to new students, since Master’s programs are not free anymore. But, it is an advantage for European and American universities, especially, since the start of the 5–100–2020 program, where joint or double degrees from foreign universities are greatly valued.

There are smaller related issues with partial incompatibility of the semester periods, enrollment processes and timelines, exam procedures, evaluation systems, grade registrations, credit point workload, exit qualifications, student feedback, etc. All these questions are not fully discovered yet, and the only way to solve them is by trial and error. The second intake of students will have a much better start, after the first students have walked the road and put the sign posts.

While, we are now considering just one particular programme between a Russian university and a Dutch university, these global issues and solutions are generic and applicable to all joint educational programs established between EU or USA and developing (BRICS) countries.

2.4. Why University of Amsterdam and ITMO University?

The University of Amsterdam (UvA) was founded in 1632 and today ranks among the top 50–100 universities in the world. UvA provides excellent opportunities for multidisciplinary education and research thanks to some of the most advanced computing, networking, storage and visualization facilities in the world. The Faculty of Science at UvA has more than 70 international master programs including MSc in computational science [3] established by Professor Sloot’s research group [4].

The ITMO University is the leader in informational technologies in Russia and the World Champion in ACM International Collegiate Programming Contest, see Fig. 1 and Table 1. In 2010, the ITMO

\(^5\) Most countries in Western Europe speak either Latin (Romance) or Germanic languages, whereas Russian belongs to the Slavic branch, very different in structure, grammar, vocabulary and sounds. In addition to Russian, many federal regions have their own co-official languages, often belonging to a completely different language family. Latin (Romance), Germanic and Slavic (Russian) languages belong to the Indo-European family; whereas southern and eastern regions of Russia speak languages from Finno-Ugric, Turkish, Uralic families.
Faculty of Information Technology and Programming and eScience Institute won a 150 million ruble (3.5 million Euro) grant for setting up an Advanced Computing Lab [5] under the leadership of Prof. Sloot [6].

Within this project, researchers worked together on cutting-edge computational science problems in complex networks and dynamical systems [17,18], in adaptive load balancing for distributed computing [20], in virtual problem-solving environments for semiconductor research [21,22], in artificial intelligence [23] and finite element models [24] for flood early warning and decision support systems [25,26]. Another goal of the project was development of joint educational programs. Based on our previous experience [3,27,28], we launched a double-degree Master’s Programme in Computational Science and held the first International Young Scientists Conference, which resulted in a special issue of the Journal of Computational Science [7].

The education in computational science is supported within various projects of the Russian Government and President. The first program on Supercomputer Education was held in 2010–2012 http://hpc.msru.ru/?q=node/117. More than 40 Russian universities participated in this project and more than 100 courses were designed for Bachelor and Master Programs. It created a strong foundation to train specialists and researchers in computational science. In that project, the ITMO University played a flagship role in the area of designing international joint educational programs, including our new Double-Degree Master’s Programme in computational science.

The decision to combine efforts in marrying Russian educational system to European standards emerged as a logical continuation of a long-term scientific cooperation of the ITMO eScience Research Institute and the UvA computational science group.

2.4.1. The excellence of students in ITMO University and career opportunities

According to the Report of the Higher School of Economics on quality of students admission to the state universities http://goo.gl/3UVsOH, out of over 650 universities in Russia, ITMO University is #7 in quality of the enrolled high-school graduates and #1 in the number of scholarships in the field of Informatics & Computer Science (see Table 2).

The main criteria of a program selection for a student are career opportunities and future salary. Statistics of salary offers in Russia –based on over 2 million open positions collected from a hundred job search requests in websites Superjob.ru, HeadHunter.ru, Rabota.ru, Job.ru- shows that the highest salary is offered in engineering positions with higher education in Applied Mathematics, Computer Science and ICT. In St. Petersburg, an entry-level engineer earns about 1000 Euro/month, 30% higher than an HR of finance specialist, and nearly 2 times higher than a shop assistant or other vacancy not requiring higher education. With an average monthly salary in Russia of 26822 rubles [29] (around EUR 600), ITMO graduates can earn twice as much, working as researchers, programmers, web-designers and alike. The demand for master programs in ICT

<table>
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<tr>
<th>Win</th>
<th>Country</th>
<th>Institution</th>
<th>Most recent</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Russia</td>
<td>Saint Petersburg State University of Information Technologies, Mechanics and Optics</td>
<td>2015</td>
</tr>
<tr>
<td>3</td>
<td>Russia</td>
<td>Saint Petersburg State University</td>
<td>2014</td>
</tr>
<tr>
<td>3</td>
<td>China</td>
<td>Shanghai Jiao Tong University</td>
<td>2010</td>
</tr>
<tr>
<td>3</td>
<td>United States</td>
<td>Stanford University</td>
<td>1991</td>
</tr>
<tr>
<td>2</td>
<td>Poland</td>
<td>University of Warsaw</td>
<td>2007</td>
</tr>
<tr>
<td>2</td>
<td>Canada</td>
<td>University of Waterloo</td>
<td>1999</td>
</tr>
<tr>
<td>2</td>
<td>United States</td>
<td>California Institute of Technology</td>
<td>1988</td>
</tr>
<tr>
<td>2</td>
<td>United States</td>
<td>Washington University in St. Louis</td>
<td>1980</td>
</tr>
</tbody>
</table>
and Computational Science steadily grows and appears a lucrative undertaking for potential students.

One of the competitive advantages of our double-degree Master’s program from ITMO University and UvA is its novelty and uniqueness. This program will teach students to build computational models from real-life observations, to turn these models into computational codes and to perform large-scale simulations. These skills are in high demand all over the world, both in industry and academia. A Master’s degree from a TOP-100 university gives extra opportunities to go for a PhD in prestigious universities or to work in international corporations, where Russian degree would not mean as much as a degree from the University of Amsterdam.

Above all, studying in The Netherlands is a happy and exciting experience for Russian students. Dutch people are very open and friendly with foreigners, and the University of Amsterdam is oriented towards international students and offers a number of services and support facilities to ensure smooth and pleasant stays and efficient study process.

<table>
<thead>
<tr>
<th>#</th>
<th>University</th>
<th>Average grade of enrolled students (max. 100 points)</th>
<th>Number of scholarships</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>St. Petersburg State University</td>
<td>92.5</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>Moscow Institute of Physics and Technology</td>
<td>92.3</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>Higher School of Economics, Moscow</td>
<td>91.7</td>
<td>111</td>
</tr>
<tr>
<td>4</td>
<td>Novosibirsk State University</td>
<td>88.0</td>
<td>75</td>
</tr>
<tr>
<td>5</td>
<td>National Research Nuclear University, Moscow</td>
<td>87.4</td>
<td>148</td>
</tr>
<tr>
<td>6</td>
<td>Russian Presidential Academy of National Economy and Public Administration, Moscow</td>
<td>86.0</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>ITMO University, St. Petersburg</td>
<td>84.9</td>
<td>269</td>
</tr>
<tr>
<td>8</td>
<td>Higher School of Economics, Nizhny Novgorod</td>
<td>83.9</td>
<td>16</td>
</tr>
<tr>
<td>9</td>
<td>Financial University under the Government of the Russian Federation, Moscow</td>
<td>83.1</td>
<td>61</td>
</tr>
<tr>
<td>10</td>
<td>Voronezh State University</td>
<td>81.9</td>
<td>84</td>
</tr>
</tbody>
</table>

3. Double-degree Master’s programme “Computational Science in Multidisciplinary Research”

In 2012, the University of ITMO and University of Amsterdam launched a double-degree Master’s program Computational Science in Multidisciplinary Research. The program takes two years and gives 120 ECTS credits. During the first year (60 ECTS) students study at ITMO University, and the second year (60 ECTS) they spend in UvA. The credits earned in the partner university are mutually recognized by the other partner. In the end, students defend their master thesis and obtain two Master’s degrees: from UvA and from ITMO.

The two prerequisites are as follows: (1) Bachelor’s degree in the field of computational science or equivalent, completed with good grades; and in UvA (2) Sufficient proficiency in the English language. The minimum score required on the TOEFL Internet-based test (iBT) is 90, IELTS test: 6.5, and a Cambridge Examination Score with a minimum test result of CAE A or B http://goo.gl/lzLtCn

The education in ITMO is free. Good students receive a stipend from the government and in addition have a chance to work (part-time) in research projects to earn money for independent living in the Netherlands. One of the biggest advantages of Russian state universities is the state-subsidized student lodging provided for the non-residents for an extremely small fee (20–30 times lower than in Amsterdam). The tuition fee in UvA is 1835 Euro (in 2014). This is a special arrangement for our programme, it is nearly 10 times lower than a regular fee for foreign students outside of the European Union, thanks to the support from the board of the UvA.

In addition to the regular studies, the students participate in the annual Young Scientists Conferences http://acl.ifmo.ru/?ws=15 and in Summer Schools organized by UvA and ITMO universities. A two-week Summer School on Large Scale Complex Systems Simulation was planned in July 2014 together with the SkolTech and MIT. The first week was planned in Amsterdam and the second week in St. Petersburg. Twenty students from Russia and twenty students from the Netherlands were selected based on their academic achievements and research motivation. Top experts in the field of complex systems simulation were invited to give lectures and master classes. Alas, due to some undisclosed reasons, the School was canceled by the University of Amsterdam.10

3.1. Curriculum

Competencies: According to the Bologna Process, Russian education is moving toward a competency-based system. Our courses are covering three levels of competencies:

1. Social and personal competencies in communication, ethics, linguistics, teamwork, etc.
2. General scientific competencies in mathematics, natural sciences, economics, etc.
3. Professional competencies specialized in the area of Master’s degree, organizational skills, etc.

Core courses in the first semester (see Table 3) develop the basic knowledge and skills in the field of applied mathematics and informatics, parallel computing technologies, and software development. Core Courses in the second semester lay the foundation for modeling and simulation in various fields of science and teach

10 Although no official explanation was given for the Summer School cancellation, most students and people involved in preparation believe it was politically motivated, because of the tensions between EU and Russia over the situation in Ukraine in spring of 2014. We believe that canceling our School was a mistake, because collaboration in science and education is a sacred cow that shall be nurtured in spite of any tensions or sanctions. Science and education bring progress to Humankind, develop Civilization, and establish true Human values. Only through cooperation and mutual respect—especially in difficult times—can we sustain a harmonized development of the World. Capitalized words emphasize that we humans share a small world, which is getting ever more intertwined.
Table 3  
Curriculum of the double-degree Master’s Programme in computational science. Credit points are given in the European Credit Transfer System (ECTS).

<table>
<thead>
<tr>
<th>The First Semester (ITMO)</th>
<th>ECTS</th>
<th>The Second Semester (ITMO)</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Parallel Programming Technologies</td>
<td>6</td>
<td>2. Discrete Mathematical Models</td>
<td>6</td>
</tr>
<tr>
<td><strong>English language courses:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Academic English</td>
<td>3</td>
<td>5. Design and Analysis of Algorithms</td>
<td>6</td>
</tr>
<tr>
<td>2. Scientific Writing in English</td>
<td>3</td>
<td></td>
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</tbody>
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<thead>
<tr>
<th>The Third Semester (UvA)</th>
<th>ECTS</th>
<th>The Fourth Semester (UvA or ITMO)</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Five of the elective courses:</strong></td>
<td></td>
<td>Master’s research project (30 ECTS)</td>
<td>30</td>
</tr>
<tr>
<td>1. Complex Systems Simulation</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Evolutionary Computing</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Scientific Visualization and Virtual Reality</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Geoinformatics and Geocological Systems Simulation</td>
<td>6</td>
<td></td>
<td></td>
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<tr>
<td>5. Bioinformatics</td>
<td>6</td>
<td></td>
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<tr>
<td>6. Computational Finance</td>
<td>6</td>
<td></td>
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<tr>
<td>7. Forensic Informational Systems</td>
<td>6</td>
<td></td>
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<tr>
<td>8. eScience Infrastructures</td>
<td>6</td>
<td></td>
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<tr>
<td>9. Non-linear Economic Dynamics</td>
<td>6</td>
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</table>

3.2. Timeline of enrollment and studies

The total duration of the program is 2 years, see Fig. 2. The program starts in September. The admission process in ITMO begins in March and closes on June 25. Foreign applicants who need a student visa should submit their documents before April 1. To enroll in ITMO University an applicant should pass an entrance interdisciplinary exam in the first half of July.

To enroll in the University of Amsterdam a prospective student should fill in an application form before February 1 next year, submit the results of an English language test (TOEFL or IELTS) before May 1, and provide the transcript of records in July. Students are then enrolled in UvA in July and receive the residence permit and visa before July 15. After that the students register for the first-block courses 4 weeks before the start of the second academic year, i.e. by the end of July. The UvA introduction week helps the students to prepare for their studies by offering lectures and crash courses and organizing Amsterdam city tours and night parties.

In the end of the second year, students have to defend their Master’s theses. The option to submit the thesis only in English, without a Russian translation, is one of the many unique features of our program in Russia. The united examination board consists of the supervisors and experts from both universities, and from the representatives of other institutions and business organizations. A link to the potential employers is a relatively new requirement introduced by the third-generation educational standard of the Russian Federation.

3.3. Research topics of Master’s projects

Students select a research topic for their Master’s project from one of the many application fields of computational science. They solve real-world problems by developing software that utilizes high-performance computing resources and e-Science infrastructures. That involves data assimilation and processing (including Big Data), decision support systems, and urgent computing applications [30] with dynamic control over computational resources in a distributed environment [20]. Students take part in international research projects [5,19,25,31], and collaborate with ICT (Information Communication Technology) companies [32].

The first three Master’s theses defended in 2014 are described below:

1. Execution time estimation in the workflow scheduling problem. A workflow makespan estimation algorithm has been developed that takes into account complexity and randomness of the workflow components and their runtime. The proposed solution addresses the problems at different levels: from task to workflow, including the error measurement and the theory behind the estimation algorithm. It uses a dual stochastic representation, characteristic distribution functions, in order to combine tasks’ estimates into the overall workflow makespan.

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Additionally, the research proposed the workflow reductions - the operations on a workflow graph that do not decrease the accuracy of the estimates, but simplify the graph structure, hence increasing the algorithm performance [25, 33].

2. Genetic algorithms in modeling relativistic jets from massive black holes[12]. A new technique of finding the most appropriate description of black holes relativistic jets has been developed. Biologically driven genetic algorithms were applied to fit theoretical predictions given by a certain outflow-dominated jet model with the observational data. This method allows to avoid parameters of unknown initial approximations and therefore to avoid falling into a local minimum or even into a fitting error, which is a common problem in astrophysical optimisers. Main objects considered in the work are low-mass X-ray binaries GX 339–4 and GRS 1915+105. The algorithm provides a good fit for both sources and can easily run in parallel.

3. Twitter-based signed network clustering and simulation[13]. The goal of this work was statistical analysis and modeling of social networks. A model for generating unlabeled networks taking into account popularity and similarity effects was extended in this work for signed networks, i.e. networks with positive and negative links. This extended model was tested and validated using an annotated dataset of approximately 7000 tweets. It was found that the users formed interests groups (clusters), which cannot be explained by a random assignment of sentiment. A new model was compared to a standard Barabasi–Albert (B–A) preferential attachment model with randomly assigned sentiment (negative links). The proposed model better describes the

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real data, since clustering effect is stronger than in the standard B–A model.

Some of the research projects of the second-intake students are described below:

1. **Finding vulnerabilities of criminal systems by complex network modeling.** Fighting organized crime has been an important task of the police forces for a long time. Yet there is still no definite answer on how, having different sorts of information about the structure of a given criminal system, police can most effectively affect the system. This project works with the information collected by the Dutch police about various members of a criminal network, their roles and connections. The goal is to build a working imitational model of this system and to find an algorithm to identify the most critical members of the network, targeted removal of which will disrupt the criminal network.

2. **Data-driven analysis of the effectiveness of wearable wireless sensors for crowd control.** In India, crowd disasters often happen during religious festivals. A possible solution is to inform people about the surrounding situation by a wearable electronic device, which detects a dangerous density and leads the wearer away from the crowd [34]. In this Master project, data analysis techniques will be applied to parameterize and analyze the design and effectiveness of the electronic device.

3. **Development of a 3D in-stent restenosis model.** Stenting is a common way of treating pathological narrowing of blood vessels (stenosis). Sometimes, stenting provokes abnormal tissue growth in vascular walls, causing a repeated stenosis (restenosis) [35]. The aim of this work is to develop and validate a 3D model based on an existing 2D model and study how differences in stent geometry and deployment can affect the process of restenosis.

4. **Programme implementation results and lessons learnt**

Leading Russian universities are competing for high-quality students. A positive enrolment dynamics indicates a strong interest of the students to our double-degree programme. The number of enrolled students more than doubled in the third year, see Fig. 3. In the next subsections, we describe the results of the programme implementation per each of the three student intakes.

4.1. **First student intake in 2012**

First students were enrolled in this programme in 2012; they have graduated in June 2014. 17 students came from 7 regions of Russia and from Kazakhstan. Only four students scored high enough in TOEFL test and were admitted to UvA for their second year. All of them successfully completed the UvA courses of their choice with the grades of 8.0 and 8.5 (out of 10). Three students defended their theses with very good grades (7.5, 8.0 and 8.5) and obtained two Master’s degrees from UvA and ITMO universities. Two of these three students are now doing their doctoral (PhD) research: one in UvA and one in ETH University in Zürich. The third Master’s graduate is working in applied mathematics department in a Russian university. One student did not defend his thesis yet, but works as a programmer in an IT company. The remaining 13 students stayed in St. Petersburg and received their degrees from ITMO University only.

It was a hard lesson for an international double-degree program. We took this lesson seriously, introducing two additional courses in English for the next intake of students. Since all additional teaching falls on the shoulders of the same teachers (without extra pay or reducing other load), this practice should be a one-time effort to keep the program going. A better solution would be to impose an entrance requirement on English test for this programme, equal or slightly lower than that in UvA. This is however a disputable option, since legally Russian universities cannot request that now.

A serious problem (related to the group split-up) is the double load on teaching staff: while a few students study in Amsterdam, the rest of the group is taught in St. Petersburg. To fit the prescribed curriculum, students in ITMO should be taught the same courses that UvA is teaching, which is inefficient. Alternatively, the ITMO students could be moved to a different programme, which is difficult due to the essentially different curriculum of the first year.

4.2. **Second student intake in 2013**

In the second intake of students in 2013, 18 students have been enrolled in ITMO University, including one student from China. All students obtained state-funded scholarships fully covering their tuition fee and about 90% of their lodging expenses.

By law, we cannot demand proficiency in the English language as an entry requirement, therefore the second-intake students also had problems with the language in the beginning: only one student out of 18 had an IELTS score of 7.0, sufficient for studying in UvA. Two new English courses improved the situation: six students passed either TOEFL or IELTS test on a satisfactory level.

Out of these six, only 4 are now studying in Amsterdam. One student received a scholarship from KTH Royal Institute of Technology in Stockholm and went to Sweden. Another student enrolled in UvA but was not able to find financial funds (10,400 Euro) required by the Dutch Immigration Department to issue a residence permit. This brought us to an unpleasant discovery: a student in Russia can take a loan only with a co-borrower who is on a long-term contract with high income, as confirmed by the income tax forms.

Another serious inconvenience pointed out by the students is that they have to register twice: once in ITMO, and then separately in UvA. In addition to the two enrollment procedures they have to defend two theses in two languages with two supervisors – all this strains the students. There are two ways out:

- First, to convert the program into a joint degree, where just one set of procedures is necessary and only one degree is given jointly by two universities. This, however, is far from straightforward due to the legal and bureaucratic constraints.
- The second option is to alleviate the hurdles as much as possible. We have managed to cut down two trees so far: (1) ITMO accepts a Master thesis in one language (English) with a summary in Russian; and (2) we organized just one defense procedure (also in English), where two Master Exam Committees are present: from UvA and from ITMO.
4.3. Third student intake in 2014: admission and survey results

In 2014, we opened two additional tracks within the programme: Urban Supercomputing and Big Data and Extreme Computing, and acquired 32 state-funded scholarships for the programme, nearly twice as much as in previous years. In a view of the increased capacity, and pursuing the goal of attracting the brightest students, we launched an advertising campaign. In addition to traditional ITMO web site and Open Days, we announced the program in educational web sites and social networks. We also organized special ITMO events: open classes, student conferences and summer schools. Another interesting experiment was posting a summer job vacancy in recruitment web sites for Bachelor graduates. Two students who took this opportunity joined our Master’s program after that.

After an entry exam, 39 students were enrolled: 12 from ITMO University, 6 from other universities of St. Petersburg, 6 from European part or Russia (excluding St. Petersburg), 6 from Asian part of Russia and 9 students from other countries. The students participated in a survey that helped us understand which advertising strategy was the most effective. The results are shown in Fig. 4. Over two thirds of the students discovered our programme from ITMO sources: web site (26%), teachers and researchers (26%), events (10%) and open days (7%). Another 16% heard about the program from their friends. Educational and recruitment web sites gave 6% each, and social networks gave just 3%.

4.4. Third student intake in 2014: programming and English test results

At the beginning of the academic year 2014, the students were tested for their skills in programming and algorithm design (25 points maximum) and for proficiency in the English language (TOEFL iBT with 120 points maximum). Thirty Russian students took the test; 9 foreign students did not participate.

Fig. 5(a) shows that two thirds of the students perform well in English (TOEFL score over 60 points). They have a good chance of passing the official TOEFL test in spring 2015 with a score over 90 required for entering UvA. We also see that half of the students are good in programming (Programming score over 12.5). Eleven students showed excellent results in both tests, five of those are from the ITMO University. Students with the lower results were enrolled in the programme based on the entrance exam, which proved that they have strong skills in applied mathematics. Unfortunately, these students have a lower chance to be admitted to UvA unless they work day and night improving their English and programming skills.

Fig. 5(b) shows a histogram of a product of TOEFL and Programming scores for the students in 4 geographical groups: ITMO University, St. Petersburg (without ITMO), European Russia (without St. Petersburg), Asian Russia. The product was normalized to the highest scores in every test (96 in TOEFL and 21.5 in programming). We selected a product of the two test results (and not a summation) because it best represents a synergy of the two skills required for the double-degree international programme. As we see, the results of the ITMO students are overall higher than those of the other regions, except for the best three students from Asian Russia.

In Fig. 5(c) we summarized these results by plotting the average of a normalized product of TOEFL and Programming scores. It demonstrates that, on average, ITMO University and Asian Russia provided the best students for this intake.

5. Conclusions and future work

The trend towards global integration of the world economies inevitably leads to integration of educational systems. A special attention goes to the BRICS countries, which are eager to study in the best world universities. A brief discussion of Why and How given in this paper should have convinced the reader. There are however global issues that shall be tackled to make the joint educational programs successful, most notably (1) separation of Russian educational system from research institutes; (2) cultural differences; (3) language issues; and (4) partial incompatibility of educational systems. While the first hurdle might be only Russia-specific, the last three are definitely present in most other developing countries. While global solutions are possible in the
long run, we also suggested some short-term solutions that could be implemented with a careful planning.

Based on a long-standing collaboration between the University of Amsterdam and ITMO University, we have launched a **double-degree graduate (Master’s) programme in computational science**. Chapter 3 of this paper gives a Program curriculum description, useful links and action points essential for successful studies. Some examples of student research topics and scientific framework projects could inspire future scholars.

There are still many **open questions and challenges** in the program implementation. One example is the double teaching load due to the group split-up, when students in Amsterdam and students in St. Petersburg have to take the same courses at the same time. Another problem is the curriculum that changes every year in both universities, therefore enlisting all the courses in the agreement between the universities put restraints on the program implementation. We are now looking into ways to solve these issues.

A lot of work is being done, and much more is to be done in the future to comply with the ever-changing environment and competition. We have set very audacious goals: to make our Master’s programme internationally recognizable and to ensure that our graduates stand out from the crowd in the job market worldwide. Studying abroad, learning from the top experts in the field, working in real-world projects and taking internships in leading ICT companies made our Master’s programme very attractive to Russian students, and perhaps to a wider audience. We are now in the process of setting up the procedures that will allow **students from Amsterdam University to study in St. Petersburg**. Since the ITMO diploma per se is not a strong incentive yet (at least until ITMO surpasses UvA in international rankings), we plan to start from separate courses that would be of interest to UvA students. One of the opportunities could be an intensive training in parallel programming by the best ITMO instructors, who raised the World Champions in programming.

In 2014, we launched **two more tracks** within the existing Master’s Programme in Computational Science: **Urban Supercomputing** and **Big Data and Urgent Computing**, and acquired 32 state-funded scholarships for the programme, nearly twice as much as in previous years. The third student intake in 2014 was very successful: 39 students were enrolled, while in the first two intakes only 17 and 18 students were admitted. To understand which advertising strategy was the most effective, we conducted a survey. It showed that over two thirds of the students discovered our program from ITMO sources, 16% heard about the program from their friends, and all other sources of information (educational and recruitment web sites and social networks) together informed only 15% of the students.

The results of extensive testing showed that two thirds of the students enrolled are relatively good in English (TOEFL iBT score over 60 points); they have a good chance of passing the official TOEFL test in spring 2015 with a score over 90 required for entering UvA. A half of the students turned to be good in programming. Eleven students showed excellent results in both tests, five of those are from the ITMO University.

Another direction of future work is formalizing a **joint PhD degree** between UvA and ITMO. Three PhD students, who have been doing a collaborative research under a joint supervision and joint funding from UvA and ITMO [24,36–40], defended their PhD theses\(^\text{14}\) in September 2014, but only in UvA. The reason is that under the current Russian regulations, the future doctors in ITMO University have to pass 3 exams, translate their theses into Russian language and go through several additional bureaucratic procedures. Since PhD from UvA (one of the Top-200 universities) is automatically recognized in Russia, the future doctors obviously do not want to go for these extra burdens to get a degree from ITMO. Instead, they defend their thesis in UvA alone. This way, ITMO and Russia at large are investing resources into the honor of another university and another country, without enjoying the crops of the best young researchers recognized in the international scientific community. To avoid this apparent brain drain, Russian academic system and ITMO internal rules should be significantly improved to lure and retain bright minds.
