

# Involvement of students and postgraduates into megagrant laboratory under supervision of leading scientist Romeo Ortega at ITMO University\*

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**Abstract.** In 2010 the Government of the Russian Federation established particularly large grants aimed to attract world-renowned scientists, including compatriots living abroad, to Russian scientific and educational centres. These grants, known as Megagrants, ensure the creation of research teams that can compete with the leading world laboratories and achieve world-class scientific results. Involvement of young Russian scientists in the projects became one of the main Megagrant features: half of the participants are people under the age of 35 years. Founded as a part of this project in ITMO University the laboratory "Nonlinear Adaptive Control Systems" under Romeo Ortega's leadership is described in the paper. This laboratory was created at the Department of Control Systems and Informatics. The priority of the laboratory is the preparation and formation of a stable team able to conduct advanced research in the field of nonlinear, adaptive and robust control of various technical objects.

**Keywords:** Involvement of students and postgraduates in research; world-renowned scientists; complex technical objects; adaptive and robust control

## 1 Introduction

Currently, the Government of the Russian Federation conducts an effective policy on the development of the scientific potential of the country. In this regard, new programs of financial support of scientists, who are engaged in advanced research in priority areas, were developed. Particularly, in 2010 the government established especially large grants aimed to attract world-renowned scientists, including compatriots living abroad, to Russian scientific and educational centres. The main purpose of these grants, which are known as

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Megagrants, is in creation of research collectives that can compete with the leading world laboratories and achieve world-class scientific results. Their owners made a commitment to involve students, graduate students and young scientists in research, and thereby to promote the inflow of talented young people in education, science and high technologies. One of the key conditions for grant is the involvement of students, graduate students, young scientists and specialists in the research group. Namely, half of the participants in the projects should be young Russian scientists under the age of 35 years. Starting from 2010 about 4 billion euro were allocated on the implementation of this program. Particularly, these funds were provided for the construction and organization of 160 laboratories under the leadership of 82 foreign scientists (from 21 countries) and 78 Russian scientists. The best scientists headed these laboratories at the end of the four contests. More than a half of the laboratories are engaged in practical research. The results of their work have already found real practical application. In 2014 well-known scientist in the field of automatic control systems Ortega Martinez Romeo Salvador became one of the 42 scientists-winners of the fourth opened competition for grants with the project «Robust and adaptive control systems, communication and computing». The total number of applications for the competition (from representatives of more than 40 countries) was 503, while the citizens of the Russian Federation submitted 203 applications. In ITMO University the laboratory "Nonlinear Adaptive Control Systems" under Romeo Ortega's leadership was founded as a part of this project. This laboratory was created at the Department of Control Systems and Informatics.

## **2 Project description**

The project «Robust and adaptive control systems, communication and computing» is focused on fundamental theoretical research: an analysis of modern methods of robust and adaptive control and stabilization of linear and nonlinear dynamic objects under conditions of uncertainty, disturbances and delays, the development of control systems, decision taking, calculation and testing of control impacts to ensure the desired quality of indicators for the control of complex technical systems, dynamical systems with uncertainty, delay and non-stationary conditions. The research is based on the methods of robust and adaptive control, to be conducted within the frame of the project that is expected to suggest new control algorithms to significantly reduce the time required for controller settings and make them more comfortable in terms of technical implementation.

A rapid evolution of information and computing technologies have led to a change of control theory paradigm and formulation of highly actual problems for conducting fundamental research in the areas of mechanics and control theory, [2]. Clearly, using of digital controllers or embedded computing systems allows for a unified approach to the design of controllers for plants having various nature, which inevitably leads to essential economic efficiency and universality of control systems. More importantly the same programming and algorithmic software can be used.

Today, an increased attention is being paid to the creation of intellectual control systems technologies. These systems are designed to work in the presence of uncertainty (impossibility of exact mathematical description) in the properties and characteristics of complex plants and the environment, [3].

The necessity of intellectual control is stipulated by the more severe requirements imposed on the modern technical systems and economic efficiency of hardware implementation of the controllers. It is clear that the objectives formulated for the technical product at the planning or performance specification stage can be partly violated during manufacturing and exploitation.

Another important issue in intellectual control system design is the economic effect that can be obtained for non-mass production. For instance, one has to construct a robot which helps an injured human to go through the rehabilitation routine as soon as possible.

The conception of “Nonlinear adaptive control systems” laboratory corresponds with ideas of scientific leaders in automatic control, telecommunications and informatics about Convergence of Control, Communication and Computing (abbreviated C cubed).

The objective of the present program is foundation of the advanced laboratory “Nonlinear adaptive control systems” on the basis of the University ITMO. In perspective it is planned to involve leading scientists from all over the world, which specialize in the field of mechanics and control processes, as well to attract talented young people to such progressing spheres of the modern science and engineering as automatic control theory, informatics, programming, mechatronics, and robotic engineering. It is expected that foundation of a showcase laboratory will induce the more profound training of qualified specialists, scientific and scientific pedagogical personnel for scientific organizations and institutions of high-tech sectors of economy operating in the direction of strategic informational technologies. Realization of the present program will provide attractiveness of the engineering science for wider ranges of young people (students, graduate students, Ph.D students), who will be able to get involved into science which comprises programming, mathematics, physics, electronics, mechanics, and computing technology. Students will be able to experience opportunities associated with actualization of their theoretical knowledge in interesting and acute applied spheres such as programming and robotic engineering. This in turn will provide reproduction and renovation of scientific pedagogical, scientific technical and engineering personnel of a new generation, who specialize in the fields of strategic information technologies, mechanics and control processes. Foundation of such a laboratory can become a prototype for the foundation of leading scientific and research centers in the world.

The tasks project:

- Foundation of an exemplary laboratory of the highest level, which connects outstanding scientists of all generations who specialize in the areas of mechanics and control processes, as well as informational technologies and communications;

- Providing support for scientific, research and practical activity of students, graduate students and Ph.D. students of the university with the majors in programming, automatic control and allied sciences;

- Involvement of Russian scientists working abroad into scientific and research activity;

- Popularization of the fundamental and applied science among young researches through the involvement into computer coding for robot control systems, development and creation of walking, creeping, swimming, flying, wheel and track robots;

- Motivation of scientific initiative for students, graduate students and Ph.D. students, as well as their involvement into innovative, scientific and pedagogical activity;

- Supplying the advanced laboratory “Nonlinear adaptive control systems” with the modern equipment in order to enhance students’ skills in controller programming, design of mechatronic and robotic-technical systems;

- Intensification of students’ skills of team work within complex scientific and research projects;

- Providing appropriate conditions for self-actualization for young researches from all over the Russian Federation;

- Attraction of students, graduate students and Ph.D. students to scientific, research and design-experimental work under supervision of leading scientists;

- Creation of new principles of control resulting in manufacturing science-intensive products;

-Publication of the results of scientific, research and methodological articles in scientific journals, making presentations at scientific conferences, preparation of patent applications, certificates for industrial samples and useful models, registration of computer programs, etc.;

-Assistance for students in the field of creation and preparation to realization on the market of competitive scientific-intensive products, software, robots and equipment of a special assignment (robots' prototypes), possessing a world level of the price/quality index;

-Collaboration with middle educational centers, get pupils acquaintance with laboratory's activities.

Due to international cooperation Russian young scientists are given the opportunity to pass traineeships abroad and to apply gained knowledge for projects in Russia. Specifically, internships take place in the National Centre for Scientific Research in France (the main R. Ortega's work place), as well as in leading academic centres in the Netherlands, Sweden, China and many others, through collaboration with a number of leading academic institutions around the world. Even at the stage of the grant application preparation Romeo Ortega has formed the main condition for the University ITMO and the project team: more than a half of researchers should be younger than 40 years. At the moment, after one year the laboratory consists of 5 doctors of technical sciences (two of them are younger than 40 years), 9 PhDs (7 of which are younger than 35 years), as well as 6 postgraduates and 9 students. The priority is the preparation and formation of a stable team able to conduct advanced research in the field of nonlinear, adaptive and robust control of various technical objects. Since the duration of the project is 3 years, the research team tries to directly engage postgraduates and students into active research. Each of them is fixed to specific supervisor and works in a certain direction. In the laboratory weekly scientific seminars are organized at which researchers share relevant information developed during the project. Seminars pass generally in active way, everyone can ask questions and participate in discussions. This creates a so called scientific boiler in which young students can cook and cultivate their skills. Once a month postgraduates prepare lecture sessions, at which they make reports about their achievements in dissertations and arisen challenges. The purpose of these activities is monitoring and correction of the motion to the main goal - a successful defence of dissertation. Writing dissertation master students are given the task to continue their research in PhD thesis. Master students also can provide a new topic of research if their supervisors confirm the good level of achievements. There is a special material bonus for young laboratory employees which have scientific publications, regardless of the list of authors.

The main objective of the laboratory on three years is 20 young professionals passed through it, which are already able to work in a team and actively solve different problems in the field of automatic control.

### **3 Achievements**

A large number of undergraduate students, graduate students and young scientists were involved in the research work during the operation of the laboratory. Young professionals have received themes of their diploma works and master's theses, which are related to various aspects of theoretical and practical research of the project. As a result of their collaboration with world-known leading scientists in automation and control a number of fundamental scientific results on a robust, adaptive and nonlinear control of complex technical systems was obtained. Performance and efficiency of developed control methods were investigated in various mechatronic and robotic systems of laboratory. Proposed algorithms and methods were presented at many international conferences. As a result, numerous publications devoted to solved problems in control theory were published.

Thus, the problem of an adaptive control of MIMO (multi-input multi-output) systems under parametric uncertainty was considered, [4]. For solving this problem a control algorithm consecutive compensator for double channel plant was used. Conditions for the applicability of control law for aforementioned plant were proposed. Another considered problem was devoted to control of unstable objects with delay under polyharmonic disturbances acting on the states and output of the system, [5].

Next result is dedicated to robust control of rapid thermal processes of vapor deposition processing, which is widely used in semiconductor production, [6]. Robust control system for a family of nonlinear systems with polynomial nonlinearity was designed. It was proved that proposed control law provides asymptotic stability. Designed control scheme was implemented in practice and experimental results for a vapor deposition processing presented a good tracking performance.

Another solved problem deals with the vehicle speed estimation using the measurements of one sensor node which consist from the accelerometer and the magnetometer and located on the pavement, [7]. The experiments on the test track showed that the speed estimation accuracy is approximately 90%.

Methods of simple adaptive control of various multilink manipulator robots were investigated. The problem of adaptive control of robotic arm on the basis of consecutive compensator method was considered, [10]. Applying developed theory, control algorithms of humanoid robots were designed, [12].

One more problem is devoted to designing the driving simulator based on the Gough–Stewart platform and pneumatic computer controlled actuators, [6]. Two control laws were proposed and studied by the simulations and experimentally.

With the use of obtained theoretical methods concerning to the parameter identification of multisinusoidal signals, control algorithms of biotechnical robotic systems were developed, [11]. Several papers are dedicated to the control algorithms of unmanned aerial vehicles and quadcopters equipped with a robotic manipulator, [8,9].

Also several laboratory benches were constructed. On the basis of these benches new learning methods for undergraduates were developed, [14, 15, and 16].

## 4 Conclusion

Establishment of state grants for the organization of specialized laboratories contributes to major research centers and teams capable of solving modern complex scientific problems. Due to such grant the “Nonlinear adaptive control systems” laboratory was created as a part of Control Systems and Informatics department in ITMO University. The laboratory collaborates with different Russian and foreign universities, scientific and research organizations. Such cooperation on the one hand allows to take a fresh look on problems of modern automatic control theory, on the other hand a new actual challenges using leading researchers’ experience from allied sciences are set.

Especially should be noted the role of the laboratory in attracting of young researchers into scientific work. Having unique hardware in use allows to engage young talented specialists, master’s degree and Ph.D. candidates not only from St. Petersburg but from other Russian regions and parts of the world.

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