TECHNOLOGIES OF NETWORK ACADEMIC AND INDUSTRIAL EDUCATION IN ROBOTICS

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Abstract: *The paper considers the problems of intellectualization of mobile service robots for use in medical institutions, as well as the development of sensor-control equipment for underwater walking apparatus. To ensure these works by qualified specialists, a basic academic chair was established at "Stankin" University and the scientific-educational project "Intelligent Robotics" was launched, uniting KIAM and universities. As a result, scientific school was formed and a new educational methodology appeared, based on mini R&D works for the training of new type of engineers. The key research was: finding reliable mechanisms for the integration and continuous transformation of software, the creation of new methods of using remote sensors to form feedbacks in robots' control, as well as the search for new methods of knowledge representation for the formation of behavior synergies.*

Keywords: *Education technology, intellectualization of mobile robots control, remote sensors in feedback loops of robots, artificial intelligence technologies.*

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1. Introduction

Many research teams are trying to implement intelligent control of mobile service robots. There are two main challenges along the way — to ensure these works by qualified specialists and the search for reliable mechanisms for the integration and continuous transformation of software under development. To solve these problems, our team in several universities have joined forces to create a software and hardware environment for joint research and to formate a new type of specialists - the so-called “knowledge engineers”. This is how the scientific and educational project "Intelligent Robotics" appeared, which was launched, combining efforts of the KIAM of the Russian Academy of Sciences and universities. As a result, a scientific school was formed and a new educational methodology appeared, based on "recurrent" mini R&D for the training of new engineers (Pryanichnikov V.E. et al., 2020, 2023).

One of the mechanisms for the implementation of joint work was the organization of the International Academic and Industrial Network Consortium "Synergy". The purpose of the association is the joint use and development of universities scientific and educational resources in the field of mechatronics, robotics, control in technical systems, as well as automation of technological processes and production. To achieve this goal, professional industry centers have been established at universities. Figure 1,2 shows examples of educational equipment involved in distance learning, based on the remote use of laboratory stands. As a result, the unique experience was gained in conducting laboratory classes with remote access to educational facilities. New training courses were created for simultaneous classes at several universities on mechatronics, industrial equipment control, mastering the basics of industrial robotics, studying the kinematics and dynamics of robotic manipulators. Now the project gained access to training courses and equipment of 19 organizations on a mutual basis.

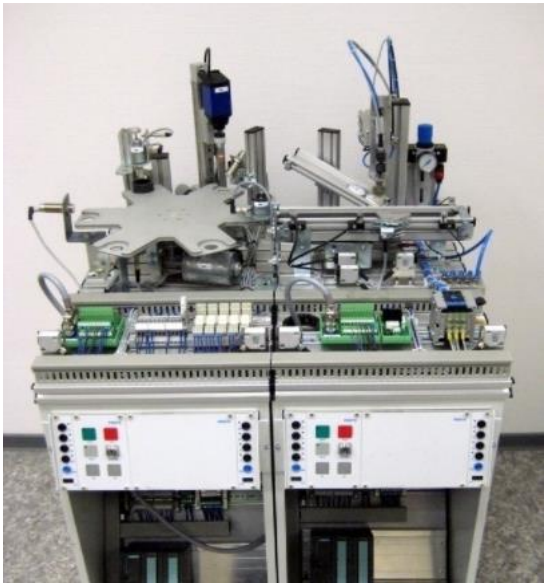

Fig. 1. Training stands for online classes.

Fig. 2. Mobile logistics platform for testing sensor equipment and for training operators in remote control.

2. The decade of cooperation agreement in the field of mechatronics, computer science and robotics

As we mentioned, several organizations, universities and laboratories, tried to find the way to combine the existing scientific and educational equipment into an experimental base. The project started in 2014 (fig.3). Thanks to network technologies, the equipment has become the basis for joint research in the field of mechatronics, the intellectualization of robotic systems, computer science, and heuristic deduction methods. The Agreement gave the Project participants the opportunity to attract additional resources to fulfil their tasks and contracts. New algorithms were developed for distributed video processing systems, scanning the external environment and controlling mobile technological robots, while providing the possibility of dynamic reprogramming of on-board systems. The results were used to create inspection, service robots and industrial shop automation (the concept of "Industry 4.0"). To attract qualified specialists to such work, the basic department of KIAM Russian Academy of Sciences "Sensor and Control Systems" was established at STANKIN Moscow State Technical University and the Laboratory at the International Institute for New Educational Technologies of the Russian State University. In this works were involved not only students, masters and graduate students, but also young researchers from sponsored schools. It is planned to further develop a new scientific and educational methodology, based on mini-research for the training of "knowledge engineers" - specialists in algorithmization of tasks and the development of expert systems in robotics. The creation of new algorithms for the operation of distributed specialized systems for processing sensor data and control signals of mobile technological robots was supported by the Russian Foundation for Basic Research, which helped the further development of scientific and educational laboratories - “robotariums”, with high-tech equipment (prototype smart grid robotics) - remote use centers for conducting joint fundamental and applied scientific research, for contact-distance, practice-oriented training. The results were published in DAAAM International Vienna Proceedings and in the scientific and technical journal "Intelligent and Adaptive Robots" (since 2006 on the base of Radio Engineering Publishing House, we published special issues of the journal included in the list of the Higher Attestation Commission). In total, about 120 scientific papers were published over 10 years and methodological-scientific book "Intelligent Robotics" (424c., ISBN 978-5-9905315-8-1), which was awarded a prestigious diploma.

Developing the Project and further cooperation we have plans in the following relevant and promising areas:

- Construction of mathematical models of service robots and the implementation of synergetic control, the use of planetary gearboxes in robotic complexes for various purposes (Pryanichnikov V.E. et al., 2023a);

- Creation of new methods for processing data from acoustic, laser and video sensors based on logic filters, FPGAs, neural networks, including for unmanned systems;
- Participation in the development of underwater robotic systems, new propulsion and power drives for them, as well as control, communication and navigation systems.

Fig. 3. Logos of the main participants in the project.

3. Education technologies

In the modern world, informal communities of scientists and specialists with congruent thinking and views on technologies for solving complex engineering problems are constantly being formed, and scientific research is being internationalized. The problem of education now is to avoid “tape recorder learning” by an innovative technology. We try to make students, capable to formalize tasks and formulate easy-to-use easy-to-implement algorithms for their treatments. Mobile robots (MR) behaviour algorithms are the most suitable area for that type of education. Thus we came to a task of designing the group of robots, interacting with students and itself.

Our approach is based on traditions. For more than a hundred years, a unique system of self-developing scientific schools has been generated in Russia. It is difficult to overestimate their influence on such an interdisciplinary science as robotics, where various scientific, technical approaches and bionic directions intersects. Academician D.E. Okhotsimsky and Professor A.K.Platonov were among the first in the USSR (since 1970) to form a team at the Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences and at the Moscow State University (MechMat faculty), which launched work on intelligent robots and walking apparatuses. The established scientific school of Academician Dmitry Evgenievich Okhotsimsky has been included in the list of Leading scientific schools in Russia. Since 1991 at the Sensorika International Laboratory (headed by D.tech.sc. V.Pryanichnikov), part of these studies received an engineering focus. In 2005, the International Institute of New Educational Technologies of the Russian State University joined this field with its robotarium to promote intelligent robotics among young people.

Today, this team of like-minded people makes up the International Scientific School "Intelligent Robotics". The community's developments are devoted to current scientific and engineering problems of intellectualization, automation in mechanical engineering and mobile robotics, including in the following areas: bionic principles of adaptive control of robots and manipulators; intelligent sensors and control systems; distributed control and simulators; mechatronics, sensorics and educational robotics. More than 300 scientific papers have been published. The Central European Branch of the Academy of Engineering in Vienna played an important role in the development of these studies. Since 2012, the annual International Doctoral School DAAAM International Vienna has been held, which helps to transfer research experience to young doctoral candidates. This was a continuation of our work with graduate students - for more than 25 years with the support of the KIAM, Central R&D Institute of Technical Cybernatics, Laboratory "Sensorika" were held International schools-seminars on adaptive robots and computer automation in St. Petersburg, Irkutsk, Kohtla-Yarva, Vienna, Divnomorsk, Moscow and other cities, sponsored the issues of collections of articles in the most difficult years for Russian science in the 90s.

4. The role of DAAAM in the education of young researchers

DAAAM International Vienna (Danube Adria Association for Automation & Manufacturing) annually holds an International symposium on current engineering and scientific issues. As part of the preparation and holding of this symposium, an international network of scientific, academic and industrial cooperation was formed, which was launched by its founder, Professor Branko Katalinic, on November 5, 1990 at the Vienna Symposium dedicated to the 175th anniversary of the Vienna University of Technology. The idea was to create a worldwide forum for engineers, scientists and industrial managers as a platform to discuss the current state and advanced manufacturing and automation technologies. Since the establishment of DAAAM International, 35 symposium have been held in countries such as Austria, Croatia, Czech Republic, Bosnia and Herzegovina, Hungary, Germany, Poland, Romania, Slovakia, Slovenia. Over the entire period of DAAAM International existence, more than 10,000 scientists and experts from fifty countries took part in it. In 2016, at the 27th International DAAAM Symposium “Intelligent Manufacturing & Automation”, held on October 26-29 in Mostar (Bosnia and Herzegovina), a section of youth research works performed by high school students was organized for the first time. The initiator of attracting future young researchers to this were the leading specialists from International Institute of New Educational Technologies (IINET) in Russian State University for the Humanities (RSUH) together with teachers from the Logos-M School, implementing the project-based teaching method. This was the first experience of the children speaking at an "adult" scientific symposium of international level with presentations made, as part of additional school education. A distinctive feature of this annual section was (that since 2016) modern digital multimedia and communication technologies for remote conferences have been used.

Since the presented research projects were carried out by small groups of students (2-3 people), some of the speakers presented their work directly in the symposium hall, and the other part at the Russian State University; a secure communication channel was organized between them via the Internet.

The virtual visual and voice associats of groups of project performers. Based on the results of the works and reports, collections of research papers of schoolchildren were published. The purpose of such publications was for students to see, that scientific research requires diverse basic knowledge, hard work and passion. A full-fledged publication was extremely important for them, as it was an indicator, that young authors meet the listed qualities, of course, in accordance with their age. Naturally, their articles and presentations were reviewed by experts, and only then, they were invited to participate in the DAAAM International symposium.

5. Examples of solved technical tasks and related scientific problem, as subjects for creative education

Consideration the scientific problems extracted from real R&D contracts became the base for organizing process, that brings students into the creative way of thinking. Let's consider 7 examples of the tasks, we used in our work with students.

1. Implementation of the visual systems for Brokk mobile robots (fig.4), were the final stages and making decisions are placed on supervisor. Requirements:

- Operating with different visual streams in parallel;
- Wireless connections with all robots and sensors;
- Comparing images from different sides, making its' transformations, scaling etc.

2. Construction of integrated information-control systems for connecting all main components of mobile robots:

- Sensors and mechanical devices, autonomous feeding systems;
- Integrating soft for on-board PC, mPCs and power electronics;
- Pre-processors for video streams integration, radio-lines, remote control units with monitors and supporting PC for distributed calculations;
- Side TV and antennas near the working area.

Fig. 4. Visual multi-channel system for mobile robot

3. Interaction technology for a group of mobile robots (use of modified Petry nets. 3D-simulation for training a groups of mobile robots' operators (fig.5).

Fig. 5. Fragment of simulator

Fig. 6. Underwater walking robot

4. Design control system for walking underwater robot with little floating satellite robots (fig.6), (Iasrebov,2024).

5. Industry 4.0 — workshop with robotic transport system (Aryskin, A. et al., 2019).

6. The mobile robot-giraffe have the main element - vertically oriented spine balancing by controlling gyroscopic moments (Iasrebov,2024).

7. Creating of the concept of robotized system for analytical control of melted metals in metallurgy (Snopkov, 2024; Sampling, 2021).

6. Conclusion

In the paper were considered the problems of creative education in the frame of the "Intelligent robotronics" project, that jointed KIAM and universities. The suggested technology is pushing the students into original R&D works. It's the main way for understanding such a subjects as robotics, control theory, etc. In future work we are planning to extend the list of investigations, create a library of laboratory research assignments for students and realize new options of the integrating software for collecting the resulted working models, control devices.

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