Classes on Artificial Intelligence, Robotics and Automation with Students of Technical Specialties

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Abstract—**This paper discusses practical aspects for classroom organization that is aimed at fundamental skill development of graduate and undergraduate school students in the field of artificial intelligence, robotics, and automation. Fundamental development training methods presented in this study are focused on improving proficiency of relevant professional competencies in accordance with the Federal State Educational Standards of Higher Education that requires a solid knowledge in both hardware and software technologies of modern electronics, automation, and robotics devices, artificial intelligence systems and a number of related areas.**

I. Introduction

For the last decades, the problem of training engineering personnel in the Russian Federation has not been given due attention. As a result, it hindered the development of Russian equipment and technology in comparison with the world level, as well as low prestige of engineering field labor, which is unacceptable for the successful development of the country. In order to handle this situation, several years ago the government of the Russian Federation set an urgent task to accelerate the development of engineering education and to attract young people to this area. The purpose of these activities is to solve engineering and technological problems and successfully contribute to the development of the country.

In order to intensify the development of engineering education, one of the current modern trends (robotics) was assigned by the Ministry of Education and Science of the Russian Federation to prioritize areas in teaching both in higher education institutions and in schools and colleges as well. At the same time, preschool and early school education also contributes to the study of the fundamentals of algorithm design, programming, and the fundamentals of robotics.

II. Teaching Programs in the Field of Artificial Intelligence, Robotics, and Automation

It is important to bear in mind that national education standards, as well as newly integrated professional standards in the field of engineering education impose strict requirements on the university students. This refers to the basics of modern electronics, electrical engineering, practical programming, mechanics, and a number of other related disciplines. Automation system prototypes and robotics are developed on the basis of these disciplines. In accordance with the Federal State Higher Education Standards, designing real

systems involves not only theoretical knowledge but also practical and professional competence.

In particular, it is necessary to have a knowledge of hardware, being able to take part in the creation of software components. Additionally, it is required to have enough expertise for practical application aiming to design architectural systems, construct and document software and hardware products, as well as the willingness to adapt applications to changing operating conditions [1].

Russian Ministry of Education focusing on the needs of the technology industry issues new education standards. It should be noted that in recent years professional standards have been developed quite extensively. All interested parties are directly involved in the development of professional standards. Thus, various non-profit organizations and companies are able to develop draft professional standards. At the same time, educational organizations of vocational education along with the other interested organizations participate in this work.

It should be noted that Russian universities are not able to directly make sufficient profits that will allow equipping their laboratories with modern technologies. Nevertheless, enterprises and organizations that are interested in finding employment for university graduates are actively involved in the educational process, especially at senior courses.

It is no doubt that future engineers and specialists need detailed, in-depth practical knowledge. That is why, in recent years, higher education institutions carried out many events and activities. Such events are as follows: opening of Technology Parks and Quantoriums with government support, an organization of specialized scientific-research communities with students, and some others. In addition, specialized classes are offered among existing disciplines. For example, the "Faculty of Information Technology" at the Russian State Social University offers training programs in the field of Informatics and Computer Science. These training disciplines are "Special sections of programming", "Software and hardware of computer equipment and automated systems." The other programs are provided for specialized training modules. The modules include practical programming (programming of real devices) based on the well-known modern platforms such as Arduino, IskraJS, Raspberry Pi and some others. Throughout the course, students learn programming environments, software, and hardware, programming languages (e.g. C++/Wiring, JavaScript, and

Python), acquire skills for building simple devices that use sensors of various information (light, movement, distance, sound, acceleration, etc.). These devices are supposed to function according to their programs (movement, signaling with sound, light, transfer, and exchange of information between devices, and so forth).

At the same time, freshmen students of the "Aircraft Control Systems" specialty of a MAI university (where a co-author of this article works) are brought through summer training sessions, which are aimed on practicing entry-level tasks in the field of "Measurement and Data Processing, Control Parameters, and Devices Automation".

The course of study involves learning guided by a teacher as well as self-directed learning. During self-study, students read textbooks, select projects, and study materials, design information processing algorithms, write programming code and test their performance in virtual development tools.

The study course on software and hardware applications contains practical exercises and tasks, starting with the level of "Flashing LEDs" and increasing in difficulty level [2], [3], [4]:

- Students use Morse code or other codes, to write their own functions;
- Sound alarm (both simplest and using Morse code or other codes);
- Using sensors (tilt sensors, temperature, humidity, light, smoke, ultraviolet radiation, buttons, potentiometer, joystick, etc.) Students also use specialized sensors: accelerometer, barometer, gyroscope, magnetometer and several others, including combined ones;
- Using various indicators: single and multi-color LEDs, LED bars, seven-segment indicators (including multi-digit assemblies of seven-segment indicators), LCD-indicators (including color graphics touch screens), LED matrices, piezo-emitters of sound, vibro-engines, etc.;
- Use of motors and servo drives;
- Study of motion control algorithms;
- Study of wireless communications, as well as the connection of automated devices to the Internet;
- Assembly of various devices (automatic and automated) applicable, including people with disabilities;
- Assembly of mobile robots.

Further training in this area is carried out by using single-board computers such as the Raspberry Pi, while students learn Python language basics along with the other programming languages [2], [3].

It should be noted that the program provides for the study of domestic analogs of the elemental electronics and hardware base, for example, the LDM-Systems company [4].

Thus, students gain knowledge and skills:

- development of Arduino IDE interface, Espruino IDE, and another programming environment;

- understanding basic concepts of a program (variables, cycles, arrays, procedures and functions, conditional statements, etc.);
- sequential and parallel execution of commands; changes in the modes of object operation, events;
- usage of libraries (both open source and independent development);
- usage of widely used electronic components for the creation of electronic circuits of automation and robotics, including domestic production;
- wireless communication between devices and communication with the Internet.

The scientific research groups for students [5] include the following the following disciplines in its curriculum:

1) Student awareness of goals and objectives of the scientific research group (for the enrolled students on this group), joint scheduling of work, discussion and approval of the topics of students' research works (SRW);

2) Teaching methods of scientific research work;

3) Conducting SRW on pre-approved topics;

4) Testing results of SRW at conferences, exhibitions, competitions; publication of research materials.

Note that the listed above activities intersect with a form of scientific and technical creativity of young people as "fab lab", in which participants are given the opportunity to assemble the required parts on high-precision machines. Technological departments of industrial enterprises periodically contact the participants, who want to manufacture and build project components.

It is noteworthy that the students enrolled on the scientific research group can act in the role of teachers on separate topics (if students have knowledge above the average level) Hence, the students not only impove their knowledge but also attract their peers to join the group.

The results of educational and creative activities of students are presented below.

A. Artificial Intelligence

Training of students in the field of artificial intelligence (AI) traditionally begins with the study of the artificial neural networks. The latter can successfully help to solve practical problems of pattern recognition. The Hamming-Hopfield neural network emulation project was carried out [6], [7]. The network consists of two layers. The description of these layers in details is as follows. The first and second layers each have m neurons, where m is the number of samples. The neurons of the first layer have n synapses each connected to the network inputs (forming a dummy null layer). The neurons of the second layer are interconnected by inhibitory (negative feedback) synaptic connections. A single synapse with positive feedback for each neuron is connected to its own axon. The idea of the network is to find the Hamming distance from the test image to all samples. The Hamming distance is a number of different bits in two binary vectors. The network must select a sample with a minimum Hamming distance to an

unknown input signal, with the result that only one output of the network corresponding to this sample will be activated.

This artificial neural network solves a particular problem with associative memory. A certain set of binary signals (in this case, images) are considered to be exemplary. The network should be able to select (given incomplete input the network is aimed to remember all previously collected data) the corresponding sample (if any) or "give a conclusion" that the input data does not correspond to any of the samples from an arbitrary non-ideal signal applied to its input. And since in this case, the signals are arbitrary images, then, by displaying the data from the network output in the graphical form it is indicated on a picture that the result completely coincides with one of the model (if successful) or the "guessing" of the network in case of failure.

The experiment of the compilation of graphic objects recognition conducted by the authors lasted a long time. This experiment was performed with a different degree of distortion of the original graphics data, as well as with a different amount of basic configuration elements. As a result, it revealed a pattern of the main deterioration feature of object's recognition with an increasing base. The problem can theoretically be solved by complicating the neural network. The authors are working in this direction to find the most appropriate solution. The first step should be the introduction of the third spatial vector for network's recognition of three-dimensional objects. At the next stage, authors are planning to change the matrix of weight coefficients so that the artificial neural network will increase its "memory" through the class of the invariant array.

Fig. 1 shows the interface window of a software. It displays sample images, as well as results of the discussed jn the above experiment.

Fig. 1. User interface of the software. User can see some sample images and buttons to conduct experiments on image recognition as a dependence of image destruction degree

Other projects in the field of artificial intelligence operate with artificial neural network algorithms in the development of expert systems (for example, a university student's rating evaluation). University departments often face similar problems in grading the students' performance. This problem involves not only grading by academic performance but also by other indicators such as: student's attitude (attendance, tardiness, retain information when skipping classes),

participation in scientific and public events, appearance, behavior, and other educational and extracurricular activities. It is necessary for reasonable distribution of a limited number of awards or special scholarships, etc.

In addition to a comprehensive evaluation (general rating), the "private ratings" of students are needed, for example, "student is a professional one in his field", "student is a novice scientist", "student is a public man", "student is a neat and responsible person", etc.

For employers, it is often important to use some special criteria for evaluating a student, namely, creativity, independence when approaching tasks and problem-solving skills, presence of special skills, etc.

Existing systems do not fully take into account the student's activities.

Therefore, it is important to solve the following tasks:

1) Development of a comprehensive and flexible system of criteria for evaluating student activities.

2) Development of a computing system capable of calculating general and private ratings of university students according to the developed criteria system.

Artificial neural network information processing algorithms (forward propagation neural network) used to solve problems.

The weights of the synaptic connections of neurons are determined by expert evaluation of each of the rating indicators. Indicators are grouped, and weight is also determined for each group [7].

There is another direction of design in the field of artificial intelligence: working with the KUKA palletizing robot. This robot was recently installed in the Technopark of the Russian State Social University. It is planned to develop software and hardware controls for special hooks and additional gadgets, both stationary (in the capture range) and attached to the moving parts of the palletizing robot. One of these projects is focused on working with handicapped people. See Fig. 2.

Fig. 2. KUKA palletizing robot, intended for various projects in conjunction with software and hardware controls and executive mechanisms on basis of Arduino, Raspberry Pi, and Iskra JS. Projects are aimed at working with handicapped people as well

B. Projects for automation and robotics

It is necessary to note that students' projects are carried out on various topics, such as "Smart Home", "Room Parameter Evaluation System with LED Color Display", "Weather

Station Project", "Human Psycho-Physical Condition Diagnostic Device", "Device based on a palletizing robot KUKA for handicapped people", "Intellectual self-learning control system of movement of an object based on neural network technologies", the development of other various projects on the microcontroller boards. All these projects can be united by a common thematics of robotics, automation and artificial intelligence.

Fig. 3 shows the operation of the Smart Home [8], [9]. Here it can be seen the general scheme, which consists of two parts: functioning in automatic mode and working under the control of external commands. The device is made on the basis of several microcontroller boards Arduino and IskraJS. These boards work together, see Fig 4.
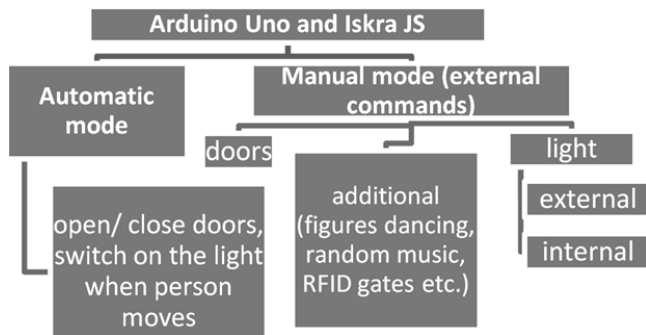

Fig. 3. Smart Home operation scheme. Two branches represent automatic mode function and operation under the control of external commands
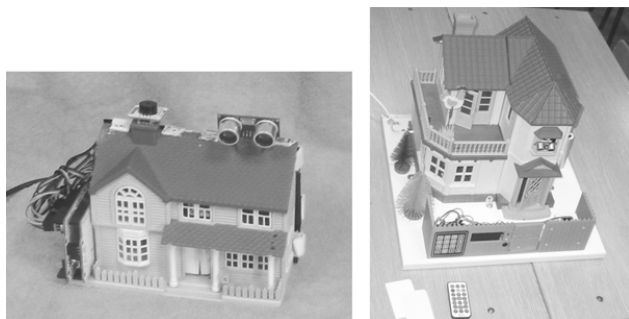

Fig. 4. Smart Home models are assembled with various options and have different functionality.

Students developed a system for evaluating room parameters with LED color display (weather station) based on the microcontroller systems studied, see Fig. 5 [10].

All student projects used free software.

The students have designed a device for diagnostics of the psychophysical state of a person on the basis of photoplethysmography and cardiography, see fig. 6 from A) to D), [11]. Certain results were obtained and reported at the conference [12]. The project is under further development, see Fig. 6.

Currently, quite a few promising projects are being implemented, for example, palm thermography diagnostics of person's characteristic properties [13].

Fig. 5. System for room parameters evaluation with LED color display (weather station). The indicators on the right side of the front panel are adjusted in accordance with the sanitary and epidemiological standards for this type of premises
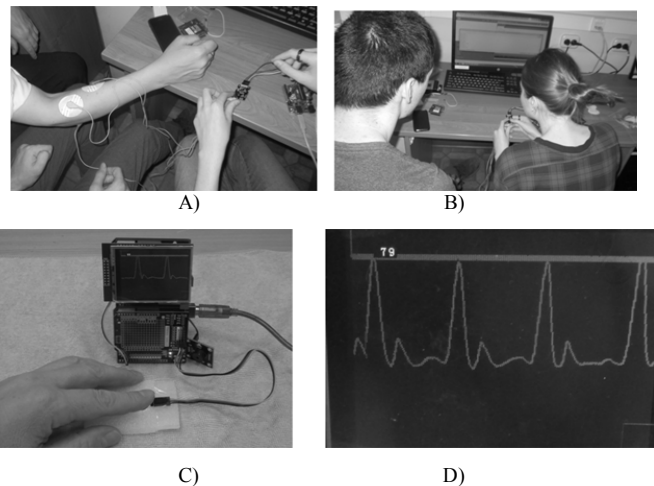

Fig. 6. Device for diagnostics of the psychophysical state of a person on the basis of photoplethysmography and cardiography.
A) Sensors test.
B) Study of tabular data - measurement results.
C) Photoplethysmography sensor [11], software (one of the specialized libraries) was rewritten.
D) Type of photoplethysmogram

One of the most engaging projects is a system design for optoelectronic measurement of vibrations and displacements, which is based on using an individual image of an object [14], [15]. In this particular project, raster conjugation is organized. Specifically, the projects focus on overlaying the optical image of the measurement object (or a contrasting light mark on it) on the analyzer. In this case, dependences of the measurement result on a number of parameters are formed. Analysis of these parameters reveals, that some of them are informative, while others are non-informative, which appear to be an obstruction.

The mathematical modeling formula is introduced below. Let the light mark, which is projected to the photocathode, is described with a two-dimensional function of brightness $E(x,y)$ of approximately symmetrical shape. Sensing of light information is conducted by aperture $H(x,y)$. Vibration

measurements along one axis (X) produces a voltage on the output of light-electronic transformer:

$$U_{out}(t) = K_1(x) \, R_l \int_\sigma E(x(t)) \, H(x(t)) \, dx \qquad (1)$$

where $K_1(x)$ – the function of non-equal sensitivity of aperture along X axis, R_l – loading resistor, $E(x(t))$ and $H(x(t))$ - light and aperture functions correspondingly, σ - work area. For the selected principle of measurements the displacement of the object x_{ob} produces the output voltage (if the scanned function is periodical one):

$$U_{out}(t) = K \, R_l \int_\sigma E(x-x_{ob}) \, H(x-F(t)) \, dx \qquad (2)$$

$(K_1(x) = K = \text{const})$.

For every special kind of functions $E(t)$, $H(t)$ and scanning function $F(t)$ one can derive $U_{out}(t)$. Let $E(t)$ and $H(t)$ are indicator functions, (like $E(t) = c$ inside the interval [-e, e] and it equals to zero outside of interval; $H(t) = b$ inside the interval [-d, d] and it equals to zero outside of it), and $F(t)=A\cos\omega t$, where ω – is scanning frequency. Then if $x_{ob}=const$ $U_{out}(t)$ can be presented as Fourier series (the expression is large enough and will not be described here).

As a result, the amplitude of the first harmonic (k =1) is:

$$a_1= b \, c \, (2/\pi)\beta(\sin \varphi_3 - \sin \varphi_0) - x_{o\delta}(\sin \varphi_1 + \sin \varphi_2 - \sin \varphi_0 - \sin \varphi_3) - \alpha(\sin \varphi_2 - \sin \varphi_1) + \tfrac{1}{2} A(\varphi_3 + \varphi_0 - \varphi_2 - \varphi_1) + \tfrac{1}{2} (\sin2\varphi_3 + \sin2\varphi_0 - \sin2\varphi_2 - \sin2\varphi_1))) \qquad (3)$$

where:

$$\alpha=e-d, \quad \beta=e+d,$$
$$\varphi_0=arc \, cos(min(1, (\beta - x_{ob})/A)),$$
$$\varphi_1=arc \, cos(min(1, (\alpha - x_{ob})/A));$$
$$\varphi_2=arc \, cos(max(-1, (-\alpha - x_{o\delta})/A)),$$
$$\varphi_3=arc \, cos(max(-1, (-\beta - x_{o\delta})/A)) \qquad (4)$$

The equation (3) is the equation of measurements.

Thus, a scheme has been developed for introducing compensation into the measurement results, see Fig. 7. At this stage, this scheme is being tested using a microcontroller base.

In accordance with the described above principles, a model of vibration/displacement measuring system was constructed. Tested were several kinds of objects, for which it is hardly using the traditional vibration testing systems. These objects are as follows: fluctuations (vibro-displacement) of human skin areas - projections of the heart muscle onto the surface of the skin in the thoracic region (studies were conducted in accordance with the recommendations of a specialized medical institution); aviation engine blades (test for vibration resistance); aviation turbine coolers; elements of printed circuit boards in electronic devices; various parts of constructions; acoustic loudspeakers diffuser; active objects (light emission); several parts of engines in automobile industry; distant measurements (hundreds of meters); and some other applications. The introduced above model was also used for rotors' balancing.
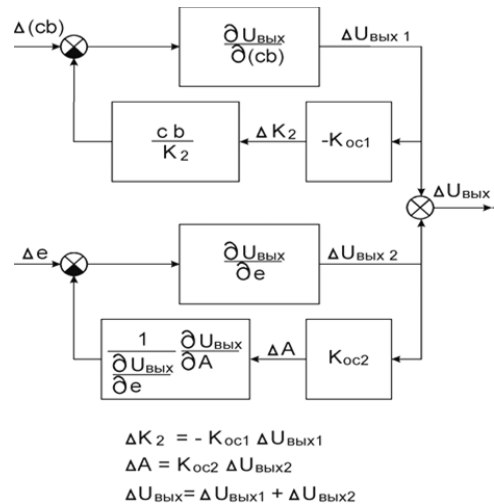

Fig. 7. Introducing of compensation into the measurement results

The research experiments related to the usage of elements in the field of artificial intelligence was conducted. The main conclusion of this research is that objects, which are taken through vibration testing, have a rather complicated structure. For example, printed circuit boards include a large number of diverse elements, or aviation electronic and distinctive types of devices. A vibration test was performed on these devices in order to improve their construction and to obtain vibration stability. It is obvious, that the vibration behavior of such boards is to be tested thoroughly. This means, that designing of a measuring system should acquire information about the vibration of a big number of spots ("objects") of this board, store it and display it in an appropriate way. It is to be noted that the measuring system is supposed to deal with various kinds of objects, which vary in size, shape, optical reflecting ability, distance to it, etc. In order to solve this problem, an intellectual robotic system is to be designed. This system represents an adaptive type, and its functions are as follows. In general, the vibration measuring of a robotic system (VMRS) should recognize borders of an object, and also deal with spots, lines, and curves of the object according to a user's choice. The VMRS should automatically scan area, defined by the user, and form a field of object's vibration, and then display it on a computer screen or make a hard-copy.

In particular, the VMRS should be able to measure vibrations of contrasting object types: spots on objects' surface; straight lines; simple and complicated curves. While performing procedure of scanning it was concluded that the VMRS tracks a line or curve, according to a user's choice. In the case of points, the VMRS searches the most relevant points and measures its vibrations one after another. Adaptive algorithms for control of a system's mode were implemented in this research work. Area of measurements is chosen by operator in a normal TV-way of search.

It is to be noted that the VMRS operations are conducted in two modes: active (usage of the special lighting system) or passive (without it). During its operation, sensors are rather advantageous, even modern kinds of them have a limited

speed of frame change, which would not allow measurements at rather high frequencies (up to hundreds of kHz).

Furthermore, several parts of vibration measuring robot-system were developed and tested. As a result, existing errors were eliminated along with the measured vibrations of objects, whose optical reflecting ability varied up to 100 times; shape varied about 30 times (for passive mode); tracked were a line of various features. This research implemented the semi-automatic algorithm for adaptation of contrasting objects during the scanning procedure. Consequently, the number of main features of various objects of measurements (some geometrical parameters) were determined, defined and calculated. In order to construct these distinct types of objects of measurements were classified, defined were the main types of "light functions", and their main features [15].

Mentioned above features were classified in order to prepare a technical task for database creation. Separate and simultaneous measurements of both linear and angular vibrations were setup, created and tested.

It is clear that the above problems and trends have a global development. For example, in the article [16] it is discussed the effect of artificial intelligence, robotics, and automation on higher education. In this article, the author in some detail examines the trends in higher education, depending on the development of AI, robotics and automation. Author especially notes that "In a short term (i.e., next 5-10 years), the higher educations will still need to train students for the industries" [16]. But at the same time the higher education itself would be changed, because "…what can be automated will be automated" [16].

Several ideas for starting projects can be taken from the books [17] and [18].

Some world-class universities offer specialized training programs on this subject. Candidates for training at Tampere University of Applied Sciences are tentatively required to be familiar with the basics of programming, digital logic and processors, and to have knowledge of machine learning and control [19].The Artificial Intelligence (AI) program at the University of Michigan comprises a multidisciplinary group of researchers conducting theoretical, experimental, and applied investigations of intelligent systems [20].

Of course students are often interested, whether there is some influence of AI, robotics and automation on their workplaces (at present or in the future), would intelligent algorithms and robots production lead to mass unemployment. Such problems are discussed, for example in [21]. As a result of constant development of technologies, educational systems and legislators are faced with the task of solving new problems. Companies, lawyers, and society in general also face these problems. In their publication [21] the authors reveal, by way of several examples, how AI will fundamentally change the world of employment.

III. CONCLUSION

This paper discussed practical aspects of classroom organization aimed at fundamental training of artificial intelligence, robotics, and automation for specialty students,

bachelors and master students. The peculiarity of conducting classes is that students need to improve their professional and professional-applied competences in accordance with State educational standards. For this purpose, classroom techniques have been developed, including research activities with modern software and hardware, based on microcontroller technology. Students learn to design and assemble working products in the field of electronics, programming, automation and robotics. It uses the achievements of artificial intelligence, for example, artificial neural networks of various types. The results of design are discussed in the classrooms, published, and presented for participation at exhibitions and conferences. It is very important to be noted that successful students can easily find employment in various enterprises, including defense enterprises (the Ministry of Defense).

Additionally, a displacement vibration system was developed and tested, which was also used for educational purposes. Principles of vibration measurements are based on the displacement of measurements of an optical image of the object. These studies outline the investigations of errors compensation, which take place because of variations of objects' size and shape, as objects usually emit or reflect different amount of light. Without using of compensation the total error would be about hundreds of percent. This is why all kinds of measurement errors were analyzed, classified, mathematically modeled and there were created special loops for errors compensation. This paper also outlined the results of the implementation of the semi-automatic algorithm for adaptation to different kinds of objects during scanning of the object's surface. Overall, it was highlighted about the principles of classification of various types of "light functions", specific for various types of objects.

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