Specialists' Training of in Industrial Internet of Things Systems Development

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***Abstract*. Training of qualified industrial Internet of Things systems developers is a key factor in the implementation of the program "Digital economy of the Russian Federation". In this paper the concepts "Internet of Things" and "industrial Internet of things" are compared. Competences of technical specialist in the development of Internet of things systems are defined. Experience of the Department of Intelligent control systems and automation (MTUCI) in training bachelors and masters in "Automation of technological processes and production" и "Management in technical systems". Laboratory workshops is aimed at providing the students with competences of the developers of It-systems are described.**

***Key words.* Internet of things, industrial Internet of things, digital economy, MTUCI, education.**

I. INTERNET OF THINGS

Network technologies are rapidly penetrating into the life of modern man. More devices become able to transmit data streams about users, environment, equipment condition to the network. Now they can be found not only in complex industries, but also in everyday life, on the streets of megacities and medium-sized cities. The adoption of the program "Digital economy of the Russian Federation" in July 2017 contributes to an increase in the pace of digitalization of everyday life of a person and society as a whole, and it's continuously related to the concept of the Internet of things (IoT) [1].

Recommendation Y. 2060 of the International telecommunication Union (ITU-T) defines the IoT as a global infrastructure for the information society that enables the delivery of more complex services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies (Fig. 1).

In the case of IoT, things are objects of the physical or information world that can be identified and integrated into the communication network.

In the discussion of IoT market, there is the identification of this phenomenon with technological solutions that support machine-to-machine (M2M) interaction, such as telemetry or monitoring the status of production facilities. Solutions in this area have existed for a long time and are actively used in engineering, transport, energy, mining, trade and logistics. M2M technologies are used in physical security and surveillance systems.

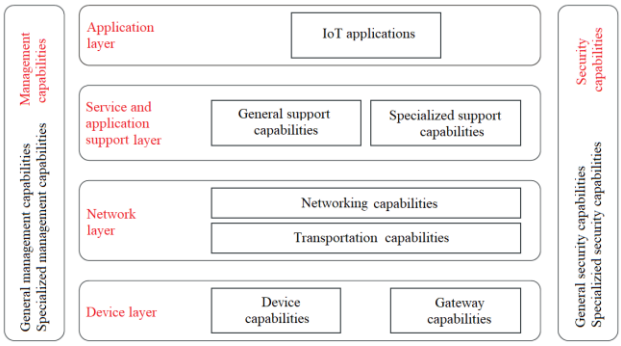

Fig. 1. IoT reference model according to Recommendation Y.2060 of the ITU-T [2, c. 7]

The use of M2M provides sufficient reliable information for decision-making, but requires human involvement for subsequent operations.

The process of transition from M2M to the IoT implies that the information obtained in the course of data mining will allow to make decisions faster and more reliable, to influence the processes without human involvement. It is the analytics of a large amount of data created by different devices that brings the process optimization to another level.

One of the technological vectors of the digital economy is the transition to the industrial Internet of things (IIoT) [3]. IIoT brings together approaches that can seriously change the industry. Some of its elements already existed before this concept took shape, simply were not put together [4].

II. PROFESSIONAL COMPETENCIES

The use of the industrial IIoT involves the creation of a comprehensive solution that combines information and production processes. This is a fairly new task for many professionals, and many factors need to be taken into account when solving it, including industry standards and processes, technological safety and regulatory framework [5].

The developer of IoT systems should have the following competencies:

- work with "things" (microcomputers and sensors): connection, administration and configuration of microcomputers and microcontrollers (Raspberry, Arduino, etc.); programming of microcomputers in C, C++ languages;

connection of microcomputers and microcontrollers with various analog and digital sensors, ADC, DAC; integration of microcomputers and microcontrollers with the Internet and data transfer to the server using wired and wireless technologies (WiFi, Bluetooth);

- creating web applications: application of IDE-integrated web development systems, for example, Microsoft Visual Studio; creating static and dynamic web pages; design of active web pages, placing controls on them; creating web services, setting up data exchange between applications;
- IoT applications development: using the IDE in the IoT area (for example, PTC ThingWorx); setting up communication between devices and IoT application; organization of data transmission and storage; applying basic knowledge to big data and machine learning; configuration of transmission of control signals from a web app to the active IoT device [6].

III. ABOUT THE EDUCATIONAL PROCESS AT THE ICSA DEPARTMENT

Modern students must have skills in developing IoT systems; it is not even a fashion trend, but an urgent need dictated by the fourth industrial revolution and the widespread introduction of IOT and IIoT concepts.

The Department of intelligent control systems and automation (ICSA) of Moscow Technical University of Communications and Informatics (MTUCI) provides training of bachelors in areas 15.03.04 — "Automation of technological processes and production", profile "Industrial Internet of things and robotics", 27.03.04 — "Management in technical systems", profile "Management in cyber physical systems" and training of masters in areas 15.04.04 — "Automation of technological processes and production", the program "Intelligent automated information management systems", 27.04.04 —"Management in technical systems", the program" Intelligent data analysis in technical systems" [7; 8].

Department educational-methodical and scientific work covers modern areas of machine learning, development of control systems using data mining methods [9–11].

As part of the educational programs of the Department, part of the disciplines aimed at obtaining knowledge in the field of digital control systems, skills to program microcontrollers and microprocessors, design skills of complex distributed technical systems. Examples of such disciplines are "Cyberphysical systems and the Internet of things", "Microprocessors in robotic control systems", "Industrial Internet of things Technologies", "Digital technologies of Smart City", "Design of cyberphysical systems", educational and pre-diploma practice.

Educational meccanos "Svyaznoy" and "Malina Z" on the basis of the Arduino module and a single-Board microcomputer Raspberry respectively are used as the material and technical base for the construction of systems for the collection and processing of information from sensors and control of executive devices in laboratory workshops.

The initial acquaintance of students with programming microcontrollers and design of technical systems begins in the first year of the bachelor's degree in the laboratory workshop on the discipline "Cyberphysical systems and the Internet of things".

The first part of the laboratory workshop is aimed at teaching students to create simple microprocessor systems for collecting and processing information.

Laboratory work "Creation of control algorithms for actuators" includes reading information from various sensors, its processing in accordance with a given algorithm and development of control commands for actuators. The state of devices (Fig. 2) can be changed by students directly in the laboratory, which adds clarity to the laboratory work.

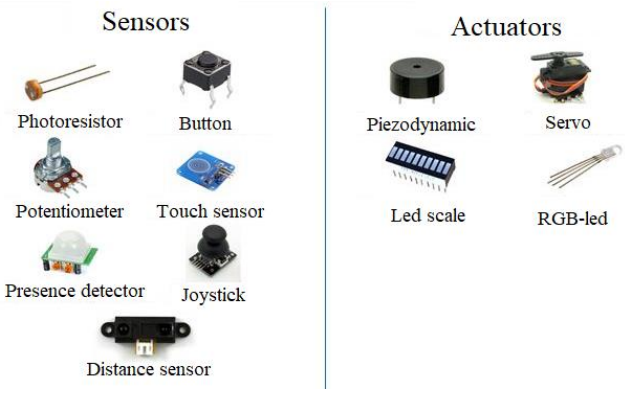

Fig. 2. Element base of laboratory work
"Creation of control algorithms for executive devices"

The purpose of the work is to consolidate knowledge of electrical engineering: analog-digital conversion, pulse width modulation, voltage divider circuit; skills of writing programs with conditions and cycles, data transfer to the PC by serial connection.

During the work, students learn arithmetic and logical operations, functions of reading and writing analog signal *analogRead()* and *analogWrite()*, proportional transfer of values *map()*, limiting the value in the range of values *constrain()*, creating conditions *if()*, cycles *for()*, gain skills in working with arrays, knowledge of methods of debugging programs to eliminate time delays in the system.

Getting students competencies in the development of IoT applications takes place in the laboratory workshop on the discipline "Microprocessors in control systems" [12].

Students are invited to develop a control system of light sources and blinds in the room during the laboratory work "Development of lighting control system" (Fig. 3).

The developed system should automatically maintain the level of illumination at a value set by the user. At the same time, user interaction with the system is performed through an application created in the RemoteXY environment (Fig. 4).

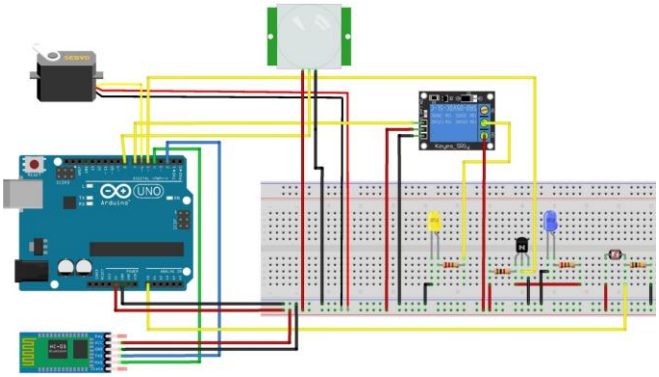

Fig. 3. Wiring diagram of lighting control system

Fig. 4. Mobile application interface for lighting control

Laboratory workshop on disciplines “Fundamentals of mechatronics and robotics”, “Microprocessors in robotic control systems”, “Technological processes in robotic logistics systems” includes the work of students with models of real robotic systems.

The prototype of the robot manipulator with elements of computer vision (Fig. 5) allows the automatic capture of objects at a distance achievable for it.

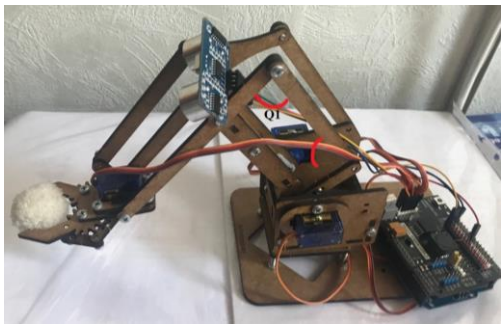

Fig. 5. The prototype of the robot manipulator with elements of computer vision

In the process of switching elements of the system and the development of the algorithm of the system, students solve a wide class of problems: from the inverse problem of kinematics to the creation of the graphical interface of the dispatching system.

The prototype of the output terminal of the automated warehouse of the manufacturer (Fig. 6) is used in the performance of a cycle of laboratory work, during which students need to design and implement a complex algorithm for the supply of goods from stores located in a row at the top of the layout and equipped with dumpers, and their consistent stacking in the truck body using a “boom” controlled by a servo drive.

Fig. 6. The prototype of the output terminal of the automated warehouse of the manufacturer

During the design of the algorithm, students use the methods of Queuing theory, and during its implementation write a program that controls the actuators at the physical level, and the operator interface of the output terminal.

The above-mentioned laboratory workshops allow students to get the full range of competencies required by the modern developer of Internet of things systems, including for industrial applications.

IV. SAFETY AND RISKS

Problems of fault tolerance and safety of the created systems come to the first place when testing them at the logical and physical levels [13].

Libraries and user applications may contain errors that lead to vulnerabilities. Within the security of the IoT, students need to evaluate what is the probability that any given IoT devices have errors. What is the probability that some of these errors represent vulnerabilities? How likely are these vulnerabilities to be exploited now or in the future?

These issues are discussed in the performance and demonstration of laboratory work, lectures and seminars.

V. SUMMARY

The IoT is one of the leading and actively developing technological concepts that can radically change all spheres of human life, including industry.

Training of specialists capable of preparing the technological base for the implementation of the program “Digital economy of the Russian Federation” is a priority for technical universities.

The ICSA Department of MTUCI implements bachelor's and master's programs, in which students get the key competencies of developers of Internet of things systems with a focus on robotics and industry.

For comprehensive and all-round professional development, students are taught all stages of IoT systems development, from design and assembly of "field" level equipment to creation of dispatching systems, testing of created programs, analysis of their safety and fault tolerance.

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