Scientific-educational centres ‘Embedded systems of automation and computer engineering’ as the basis of training of domestic specialists in the field of microprocessor technologies, electronics, distributed systems and embedded technologies

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Scientific-educational centres 'Embedded systems of automation and computer engineering' as the basis of training of domestic specialists in the field of microprocessor technologies, electronics, distributed systems and embedded technologies

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Abstract. Nowadays embedded control systems are used everywhere, including rapidly growing areas, such as 'Internet of things'. There is a need of highly qualified specialists. In this paper authors consider the organizational, methodological and technical aspects of the training professionals in the field of embedded automation. Also proposed the approaches to solution of described needs, based on the experience of the organization of the Interdepartmental Centre of Embedded Systems of Automation and Computing. Attention is paid to the developed methodologies, microcontroller-based equipment and software-hardware complexes and it practical uses. In conclusion, authors confirm the importance of developing all possible specialists training aspects.

1. Introduction

The concept of 'Embedded Control System' has a fairly long history of existence and well-established terminological meaning, which, in particular, is illustrated by many independent sources, including [1, 2]. In the article, the meaning of ECS is the control system of a technical object or process, which contains a control device (mainly based on specialized microprocessors, microcontrollers, FPGAs and other elements of computer technologies), which is integrated constructively, systemically and technologically with the control object [3].

The scope of embedded systems is extremely wide and extends from on-board special-purpose systems to household devices; The technologies of territorially distributed embedded systems that exchange information without the participation of an operator are actively developing and known as 'Internet of things'.

Professionals specializing in embedded systems are characterized by complex interdisciplinary knowledge and practical skills in the field of control systems theory, digital and analog electronics, circuit technology, computer engineering, algorithmizing and programming. The specifics of practical activities in this area include the ability to perform a complete development cycle (from pre-project

investigation to the release of operational documentation) of special purpose computer systems (on-board, embedded, with extreme operational parameters); to the specifics of scientific activity — is the ability to develop new scientific foundations and technical principles for the creation of management systems that ensure the achievement of high quality indicators of their functioning under normal and special conditions.

The pace of development in this area of science and technology is quite large; For ex., the volume of output of only one kind of hardware platforms of embedded systems - embedded microcontrollers — already have reached the level of 16 billion units. per year, which is much higher than the annual output of general-purpose computers (about 500 million units per year).

The existing methods of training professionals in automation do not fully correspond to the technical aspects of embedded systems. This paper proposes approaches to the organization of studying, taking into account the systems of knowledge and skills, that allow a university graduate to perform professional activities in the development of the latest embedded systems

2. Organizational aspects

The training of specialists in such a dynamically developing field is carried out in many educational institutions, including those widely known on the world stage: Embedded system institute (The Netherlands) — under the program 'Embedded systems engineering' [4], international Embedded Systems Academy (Sunnyvale, USA and Barsinghausen, Deutschland)[5], Institute of Information Technologies, Mechanics and Optics ITMO (Russia) — under the program 'Designing of embedded systems' [6]; The international program of the European Master's Program in Embedded Computing Systems is also actively developing [7].

In the current stage of development of the national higher school, there is an approach to the organization of training of specialists in the field of embedded technologies, based on the creation of specialized scientific and educational structures in the profile faculties and technical institutes of higher education. Such structures, having the scientific, scientific/educational or international status, will be able not only to concentrate and effectively support the educational process in the field of digital and analogue electronics, circuitry, microprocessor and computer technology, but also to develop the scientific component of the embedded systems area.

3. Methodological aspects

The expansion of the capabilities of modern automation systems for analysis and synthesis, which is typical for any field of technology, has also affected the area of embedded control systems: traditional approaches to their design are beginning to be actively supplemented with new ones. Despite the increased efficiency of the development process (in terms of reducing the labor costs of the developer and reducing the requirements for the level of his skills), the application of these technologies often results in inefficiency in the result of the development (in terms of the overall complexity of the ECS, its frequency and other characteristics).

A reasonable solution to the emerging contradiction between the goals and tasks of the actual development process (including support for the so-called 'big' projects, compliance with the terms and the development budget), and the goals and objectives of applying the development result (in the above sense of effectiveness) is the provision to the developer of technologies and tools that provide the possibility of finding a compromise between simple tasks and future use. It is obvious that the developer, who has a thorough knowledge of the design process and has the skills to manage this process, has significant professional advantages and provides a greater economic effect of its activities.

The foregoing is even more important from the point of view to the formation of new generations of developers, especially taking into account the scale of the ECS sphere and the importance of preserving the domestic development schools.

In this aspect, the problem of creating methods for teaching the disciplines of the cycle 'Embedded Automation Systems and Computing Engineering', ensuring the fundamental nature of education in this

sphere, the professional 'longevity' of the trained specialist, his ability to adapt to changes in the field of embedded devices becomes of special importance [8–11].

Further, the specialist can apply the basic, fundamental knowledge obtained in the most relevant spheres of the ECS, such as 'Internet of thigs' and various intellectual systems, based on fuzzy calculations.

4. Technical aspects

As in the process of research and development, as well as in the process of training specialists in the field of designing the ECS, it is essential to achieve the result of the development in the form of naturally implemented systems. One of the ways to achieve this goal is to use the hardware and software simulators. Most large manufacturers of ECS also offer demonstration and research platforms for the range of their products. In this area, not only commercial firms, but also several educational institutions create their own training base.

The eclectic diversity of incompatible solutions of different manufacturers makes it difficult, in addition, to teach the developer how to work with different environments, when performing new researches and developments. This leads to an increase in the development time associated with the training on new equipment, or to a non-optimal result based on solutions known to the developer, but which are of little use for this particular task.

Thus, there is a certain gap between the preparation of the developer for the subject domain of the ECS and its subsequent professional activities in this field, as well as the problems of instrumental and methodological support of both the educational process and R & D for the ECS.

5. Experience in the implementation of the scientific and educational center

The solution of the above problems should be sought in ensuring the unity of educational and professional activity in the field of embedded control systems. Methodical, scientific and instrumental solutions should satisfy both the goals and tasks of training specialists, and the needs and specificity of their subsequent scientific and engineering work.

In SPbPU, in the Institute of Computer Science and Technology (ICST) established the inter-departmental scientific and educational center 'Embedded Automation Systems and Computer Engineering' (ISEC), whose tasks include providing a triad of activities: academic, scientific and economic.

The activity of the ISEC in the direction of improving the quality of the educational process in the structural divisions of the ISTC is associated with the assistance in preparing students for the graduating departments of the Institute.

Disciplines, that students are studying in the ISEC, are related to microprocessor technology, hardware of computer systems, control systems, real-time systems.

The staff of the ISEC developed and published methodological materials that support the educational process: monograph "Microcontrollers. Development of embedded applications" [12], 'Automated information-control systems' [13], 'Hardware platforms of embedded systems' [14].

A system of interconnected laboratories has been created in the ISEC: a basic microcontroller laboratory, a laboratory of embedded intelligent control systems, a laboratory of executive elements of automation and robotics, and a laboratory of modern embedded platforms (figure 1).

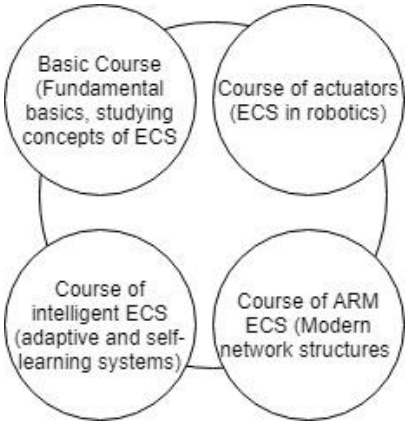

Figure 1. Interrelation of the ISEC courses.

The authors of the article patented [15] and develop a version of bench equipment for microcontroller ECS based on microcontrollers of the x51 architecture — the standard, supported by all leading manufacturers of MCS (figure 2).

The software and hardware complex with support for neural computing, based on an x51-compatible microcontroller, with hardware modules implemented in VHDL and Quartus systems, added to the processor core of the MCS-51 family (figure 5) is also widely used in the ISEC. With the use of this software and hardware complex, the complexity of analyzing and synthesizing complexes of on-chip fuzzy information converters used to develop the ECS is significantly reduced.

A system of interrelationship of educational disciplines is created, ensuring greater depth and interdisciplinarity of the educational process (figure 3).

The activities of the ISEC in the scientific direction are concentrated mainly on three components:

- Development of high-performance architectures for embedded microcontrollers with hardware support for fuzzy information processing;
- Synthesis of fuzzy information processing systems;
- Design of embedded microcontroller control systems for technical objects and technological processes.

Figure 2. Laboratory stand view.

In addition to the complex described above, in the ISEC has been developed: a mathematical apparatus for the synthesis of networks of fuzzy information processing [16], suitable for direct

implementation in embedded systems (figure 4) [17], as well as solutions for Internet-based technologies, including wireless Z-wave (figure 5 and figure 6).

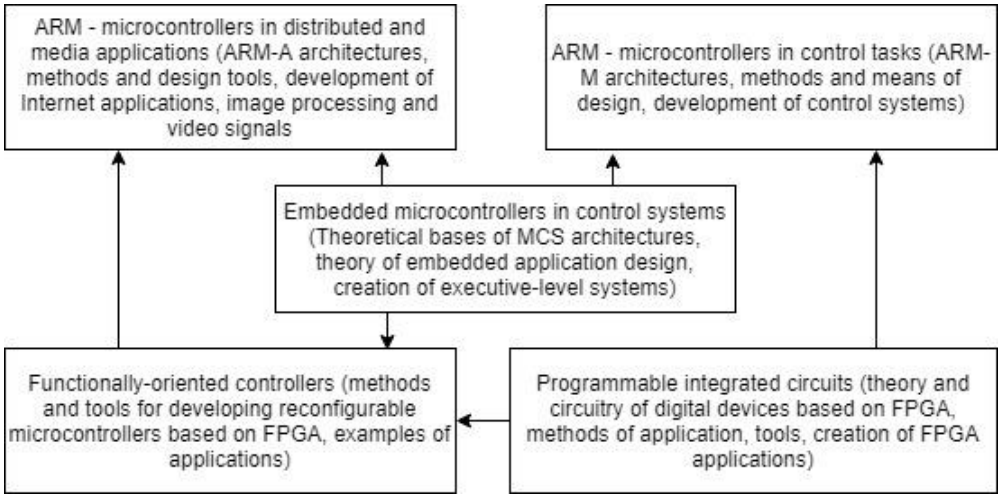

Figure 3. The relationship of the disciplines.

The activities of the ISEC in the direction of performance of contractual works are focused on the development of built-in control systems for anesthesia and respiratory equipment (in particular, artificial respiration apparatus) and auxiliary equipment (figure 7) [18, 19].

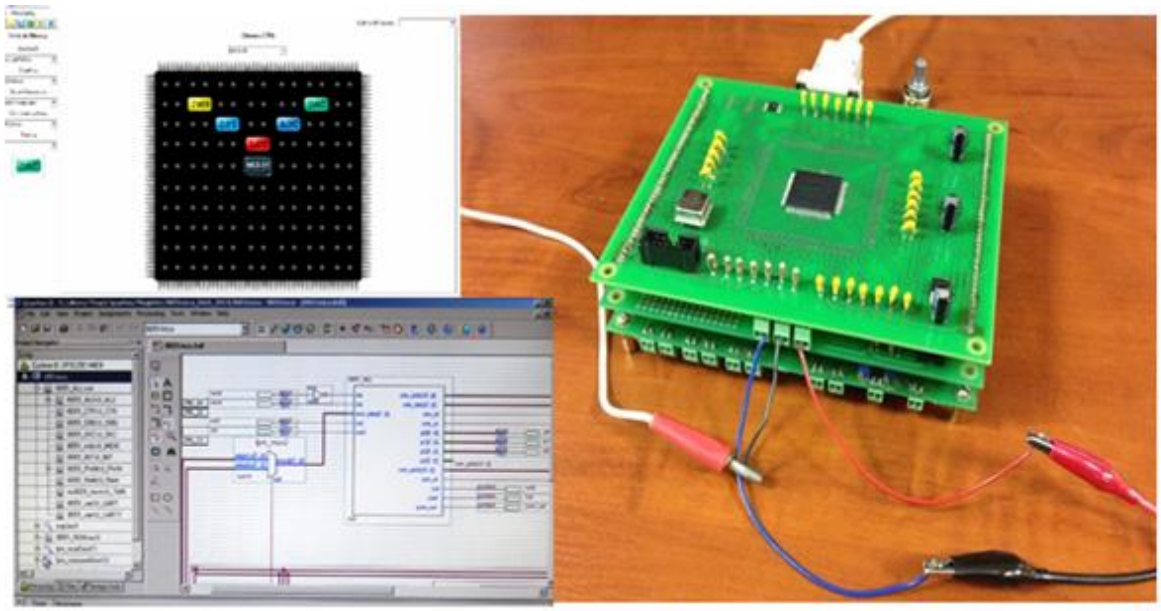

Figure 4. CAD tools for FOCs.

Figure 5. Examples of distributed 'Internet of things' and medical systems.

The described concepts, in addition to the Polytechnic University, are used in the educational process of several other educational institutions, including foreign ones. Thus, in particular, a basic laboratory 'Embedded microcontrollers' has been created at the State Technological University named after. Le Qui Dawn in Hanoi (Vietnam) [20].

6. Conclusion

To sum up, it is important to develop the proposed and create new concepts aimed at complex interdisciplinary scientific, methodological and practical research in the field of embedded applications, cyber-physical systems and 'Internet of things', which will improve the quality of professional training and strengthen the position of the domestic economy

As the experience of the functioning of the International Scientific and Educational Center shows, such an organization of laboratories, training courses and teaching staff makes it possible to increase the effectiveness of the training of specialists, in terms of quality and resources.

Scientifically significant are the development of automation systems, libraries of application programs and teaching method.

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