Interdisciplinary Approach to Cyber-physical Systems Training

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Abstract: In this paper, the authors examine the importance of a transdisciplinary approach to cyber-physical systems training. The article concludes that it is necessary to introduce new educational models that will contribute to the formation of innovative thinking of master students. The use of a multidisciplinary approach in the training of master students is substantiated, and a combined scheme of interdisciplinary and multidisciplinary methods is proposed on the example of the disciplines "Cyber-physical systems and technologies." Specialization lies in the fact that not only the available baggage knowledge, but also ways to find their knowledge in a new application, including in non-standard conditions, readiness for self-development and improvement information. The ability of the current educational model to meet the requirements has been established.

1 INTRODUCTION

The Fourth Industrial Revolution is a new stage in the development of society, the foundation of which is the previous revolution, and the main driving force is the availability of the latest technologies. Cyberspace technology has become an integral part of our world. The Fourth Industrial Revolution is based on the integration of business and society — their common goal is to empower people and organizations through the democratization of access to innovative information technologies. Restoration of economic growth and productivity is our common goal, in which new technologies will play the leading role. It remains only to answer the question, what technology will become the fundamental Industry 4.0. Thus, according to the data of the World Economic Forum, the chances of taking a leading position in cyber-physical systems (CPS) (see Fig. 1).
CPS are priority technological areas, the most relevant applications of CPS are health care, driving, performing various operations in an aggressive environment (for example, increased background radiation), industrial manufacturing.

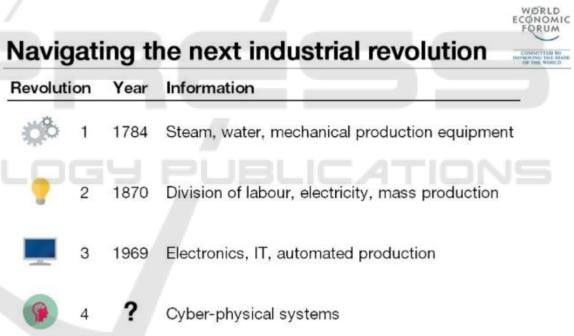

Figure 1: The place of cyber-physical systems in the development of Industry 4.0.

Thus, the purpose of this methodological manual is a prospective study of CPS (design, control systems, information security). It is expected that CPS will allow minimizing human participation in the production process, as well as in many other areas of society. Shortly, improvements in science and technology will strengthen the connection between the computational and physical elements of technical systems, thereby increasing their autonomy,

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efficiency, functionality, adaptability, security, and usability of systems of this class.

Automation of production will partially eliminate the need of enterprises for low-skilled labor, and it will be necessary to involve specialists to monitor the processes and manage the CPS.

This development raises the questions if our current educational programs are relevant or not if we need to develop new "interdisciplinary" program to teach master students, to help them to become great specialists, or should we aim for a new discipline.

2 INTERDISCIPLINARY TRAINING

Nowadays many universities all over the world, even well-known Universities, may not currently have the expertise or resource to establish CPS education programs, though CPS lies in the base of Industry 4.0. Every year things around us become more and more “independent” and “reasonable”. Virtually no device can do without its own "electronic brain". Production, research and everyday life are carried out with the participation of robots and devices with automatic control (unmanned vehicles, smart homes, the Internet of things). A person tends to devote more time to cognitive and creative activity, while complex processes provide robotic systems and SMART devices. A useful alternative in these cases is to forge more limited partnerships among several branches to implement jointly taught courses. This idea lied in the new course at ITMO University called “Cyber-Physical Systems and Technologies.” As far key CPS content could be introduced into mechatronics, robotics, or security courses cooperating of specialists from different branches help to reduce the burdens associated with CPS throughout engineering and building the courses one would need to implement a CPS program. In instance, a theory course developed to include students from computer science and mechanical engineering, as well as traditional control theory, will produce a new class of the sort that is needed for CPS.

Under the conditions of modern society, the master student becomes the central figure of the educational process, which inevitably leads to a change in the entire educational paradigm. The area of use of cyber-physical processes is very many-sided: from industrial production, construction, transport, energy saving to medicine. “Smart grids” are a prime example of the use of cyber-physical systems that combine several production stations, carrying out load balancing and pricing. The purpose of the lecturer is the creation of comfortable conditions for self-determination and self-realization of the individual. In a rapidly changing world, it is not enough to possess a certain amount of knowledge; it is necessary to have the skills to search for the information which is necessary to solve various kind of problems (design, control, security, etc). In this case, the search for information, in this case, should be understood on a broader sense - as a process closely related to the ability of the researcher to consider the problem from different angles, perhaps even in a different formulation, different from traditional approaches. Thus, a new educational model should develop in students the ability to independently develop an integrated system for solving professional problems.

3 COPYRIGHT CYBER-PHYSICAL SYSTEMS AND TECHNOLOGIES TRAINING COURSE

Educational researchers have identified some distinct educational benefits of interdisciplinary learning including gains in the ability to:
- Recognize bias;
- Think critically;
- Tolerate ambiguity;
- Acknowledge and appreciate ethical concerns.

Knowledge of the subject area, presented in the form of lectures, nodes, presentations, textbooks, scientific articles and so on form the basis for development, and the supervisor acts as a consultant whose task is not to teach, but suggest the direction of the search, to help sort out a complex issue, ultimately - to try to streamline the current knowledge of the master student. In the case of interdisciplinarity, the master student gets the opportunity to consider the problem comprehensively, he can try to develop the project innovatively, relying not only on the knowledge of his field but also using related disciplines. From a formal point of view, there is no need to be limited only to the disciplines adjacent to the specialty of the master student, but in fact, the amount of information available for meaningful processing is still limited, as is the limited amount of knowledge available. Despite the lack of academic rigor of this approach, it is entirely natural, because it eliminates the contradiction at the level of cognition.

In the case of the training course “Cyber-Physical Systems and Technologies” it was divided into parts:

1. Designing of CPS and system concept;
2. Control systems design;
3. Designing the info-communication component of the CPS;
4. The regulatory framework for CPS operation;
5. Industrial CPS design.

Each part has the main themes to be discussed can be seen in fig.2.

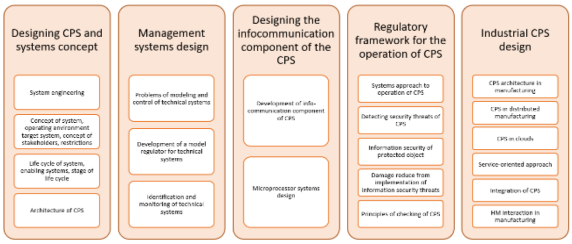

Figure 2: Themes to discuss in training course “Cyber-Physical Systems and Technologies”.

Upon completion of the discipline the undergraduate must know the computing platforms of embedded computing systems, examples of creating circuits for microprocessor technology, principles, methods and stages of the implementation of CPS; principles of checking the security of the CPS to the occurrence of a destructive information impact; be able to apply modern approaches, methods and tools for the development and operation of CPS, design alternatives; own methods of calculation and instrumental assessment of the results of the implementation of a protected CPS, the concept of the typical structure of the embedded system.

There are distinct phases during the training course for each theme (table 1), adapted for a large number of students. A total number of students in the stream is nearly 300 persons, divided into 19 student groups. The initial phase starts with a new theme in the lecture hall for the stream. Strengthening practical skills continue in student groups divided into small groups (3-4 persons) trying a study case. Now, having enough skills, it is proposed to solve a control case to consolidate knowledge.

The last phase is a final step to test knowledge and skills. To increase motivation in getting theoretical and practical fundamentals, a speaker is chosen randomly from his small group. The university applies a score-rating system on which the discipline program is based. Depending on student activity in the second phase, as well as on the quality of his speech and answers to the questions, points are awarded. Also, each theme is read and hold by a new lecturer.

Table 1: Phases for each theme in the training course.

Phase	Locatio n	Description	Duration
Initial	Lecture hall	Lection in stream (all students of the year of the department)	2 hours
Second	Seminar class	Interactive group work – analyze and carry out a study case	2 hours
Third	Home/ Library	Unsupervised work in small groups with a control case	4 hours
Fourth	Seminar class	Control case defense (randomly selected speaker from small group)	2 hours

Master students who are regularly exposed to classroom conversations and assignments that tackle real-world problems in an interdisciplinary fashion; engage in significant learning, realize cognitive gains and are better positioned to understand challenging problems and to frame viable solutions.

At the core of the course lies the teaching of core system modelling and model integration techniques based on CPS design (fig.3).

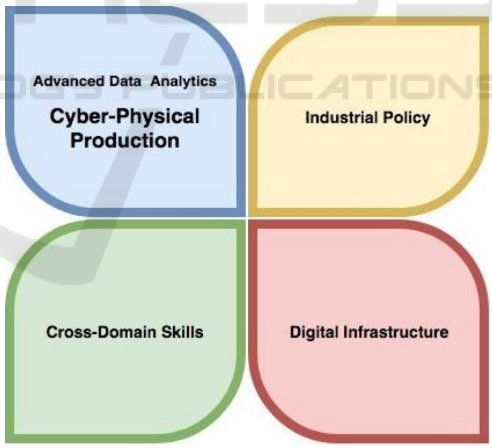

Figure 3: Core of CPS educational program.

The approach is to develop CPS specialization within existing engineering program and embedded systems. Specific tutorials and group work follow lectures in order to let master students connect theory with practice. Embedded systems and engineering program share similarities with systems engineering in the sense that they are interdisciplinary subjects. Embedded systems or engineering program can be based be taught as a separate domain.

4 CONCLUSIONS

In modern conditions, the competitiveness of a university is determined by its ability to train specialists demanded on the labor market. It is often the case that the disciplinary educational model existing in higher educational institutions does not meet the task of training a high-class specialist from modern employers and solving promising tasks in industry. The current global conjuncture of manufacture companies is massively striving to develop CPS and gives a chance to educational programs, especially technological and engineering, to become the flagships of the emerging market of CPS technologies. Today, CPS is at the first stage. In the nearest future, we expect developments that greatly simplify everyday life. “Smart” everything will independently order products in the store when the refrigerator is empty. Fitness bracelet on temperature, pulse and pressure will understand that its owner is sick, and send the information to the doctor. The front door will scan the retina of the visitor’s eyes and will not let the stranger into the house. Unmanned cars, connecting to the Internet, will choose the best route without traffic jams and relieve traffic. CPS professionals can choose from a variety of professions, from business analyst to cyber security specialist. The need for qualified employees to create and manage smart home, smart city and smart manufacturing systems is increasing every year. Disciplinary knowledge, which is often outdated or too divorced from practice, and lack of skills related to the ability to solve non-standard tasks, work in mixed groups, master new areas of knowledge, etc., are critically evaluated. An interdisciplinary approach allows us to solve a number of these problems, such as in the course “Cyber-physical systems and technologies,” where students reviewed the problems of developing the systems underlying Industry 4.0, from all sides - design study, control systems, information security, info-communication component. In a nutshell, the real-world problems are involved, so no single discipline can adequately describe and resolve all issues. The integration of branches and themes across the disciplines was achieved by carefully selecting the right content, and case studies to coincide with the computer science, engineering, security, control, and mathematics content being discussed.

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