Improvement of educational process based on software development for virtual and remote labs

Oleksandr Tarasov, Pavlo Sahaida, Liudmyla Vasylieva

Computer Information Technologies Department, Donbass State Engineering Academy, Kramatorsk (UKRAINE)

tarasov50@inbox.ru; paulsagayda@ukr.net; vasileva.dgma@gmail.com

Abstract

Principles of the use of web-based distance learning and educational process adaptation are elaborated for students of technical specialties studying various aspects of information technologies' application. Possibilities of implementation of the tasks of the development and application of remote lab (R-LAB) and virtual lab (V-LAB) technologies for the learning process to enhance practical orientation are revealed. Application of Embedded Systems for computer education and for the control of technical objects can improve students' motivation, because actions are taken with physical objects; also it can increase diversity of software systems to be created in future. Examples of the use of different software as a part of educational process for students of various technical specialties studying Information Technology are presented. In general, development of a physical object of control or management, installation of drive actuators, development of control algorithms, integration with computer systems and remote access using web-based technologies is the basis for cooperative work of students of different specialties.

Keywords: learning process, virtual lab, remote lab, embedded system, programming

1   INTRODUCTION

Higher education experiences a rapid expansion of implementation of web-based distance education, based on the use of information technology (IT). It requires a continuous improvement of technological and methodological support of educational process. This is especially important for technical specialties, as the students require access to physical objects: devices, sensors, equipment for monitoring parameters of the processes under study. One of the promising ways to improve educational process is the use of remote lab (R-LAB) and virtual lab (V-LAB) technologies for programming of embedded systems (ES) and their application for technical objects control [1-3].

It is known [2] that virtual laboratory is a combined hardware and software system allowing to conduct research without direct contact with real production or training equipment or in its complete absence. In the first case it refers to the laboratory with remote access (R-LAB), which includes actual manufacturing equipment (set), software and hardware to control technological complex (generating control signals for actuators) and analog-to-digital conversion of measurement signals from sensors installed into the equipment. It is necessary to solve a range of problems, complicated both from technical and organizational point of view, videlicet: to ensure operation of the equipment at inopportune time, reliable channel for Internet access, access scheduling and recording of performed work, transmission of video stream using appropriate equipment, etc. These objectives can be achieved, for example, by GOLDi system [4]. In the second case, the problem of emulation of laboratory equipment through the use of relevant mathematical models, as well as the tasks of control and generation of feedback signals, is implemented in software, including visualization of physical configuration of laboratory equipment for a student (V-LAB). It is natural, that the behavior of virtual laboratory unit and its appearance differ significantly from the actual equipment, resulting in a lack of competence of the students studying the subject.

An important advantage of a physical model to a virtual one is the possibility of obtaining real measurable parameters with errors for further statistical processing. Thus observation of a real physical process is more efficient for practical skills. For ES practical study a variety of teaching methods and solution of various tasks may be used. The most common for all specialties is learning of ES programming. It is necessary for the study of programming languages and available library of functions. In this case, the on-board components of ES means of information I/O can be used to obtain skills for work with a variety of sensors. The next stage is the use of ES for control and display of values of physical parameters of objects, as well as software development to manage their functioning. One more important issue is the

development of software for remote network access to ES programming and data accessing on the state of the control object.

However, for mastering of ES during the educational process it is required to be adapted in view of the content of basic training in the field of studies. At the same time it is necessary to improve the educational process technologies based on the use of IT. Therefore, the work on modernization of the educational process should be based on the development of V-LAB and R-LAB technologies by the students of the specialties studying IT for their colleagues and students of other technical specialties. In general, development of a physical object of control or management, installation of drive actuators, development of control algorithms, integration with the computer system and remote access using web-based technologies is the basis for cooperative work of students of different specialties.

2 RESULTS

2.1 Methodology of development of programmed and methodological complexes during cooperative work of students of different specialties

The study of IT in Ukraine within the framework of different specialties concerns with the study of various aspects of its application. Students of the "Electromechanical systems of automation" specialty study electrical control systems and machinery to a greater degree, while "Automation of production processes" specialty students study automation of various devices and process control. A feature of the "Information technologies of design" specialty is application of existing IT to computer-aided design of technical devices, development of application software for a variety of activities, including creation of applications for the Internet, mobile communications, data and knowledge bases, etc.

In particular, development of V-LAB and R-LAB requires knowledge in the following areas: development of models of technical objects for further study; development of virtual models for the study of their behavior; development of data exchange technologies for telecommunication networks and the Internet; development of software for integration with e-learning systems. It is necessary to ensure accounting of students' activities and results in a unified educational environment. To observe the behavior of a physical model of an object by a user development of software for video broadcasting is required.

The basis of the proposed methodology for collaborative work of students of different specialties on a project implies division of tasks on creation of laboratory works onto a number of specific objectives.

2.2 Examples of development of programmed and methodological complexes (PMC) and installations for laboratory work by students

Let us consider the developed applications and technologies during implementation of the proposed approach. For Arduino microcontroller programming skills development there was elaborated the PMC, which provides remote access to Arduino Uno (author - A. Zinjuk, Master degree student of "Information technologies of design" specialty). The PMC can be used for learning of the programming language and technologies for Arduino microcontrollers by students of different specialties. However, following from the above analysis, development and implementation of schemes to connect sensors and actuators to Arduino Uno more effectively are able to fulfill the students of "Automation of production processes" specialty, while to provide drive control of a machine or mechanism more effectively are able the students of the "Electromechanical systems of automation" specialty.

This PMC is an object-oriented software system developed in PHP language, based on Zend Framework [6]. In a group of students, who cooperate to develop a remote laboratory work, the roles are distributed as follows. The first student implements basic functionality required for the study system of ES programming using remote access. The PMC interface for mastering Arduino Uno is shown as a browser page in Fig. 1. During the program elaboration a student studies programming languages necessary for creation of a dedicated website, as well as frameworks and Application Programming Interface (API), necessary for integration of applications. The second student provides technical support of remote laboratory work.
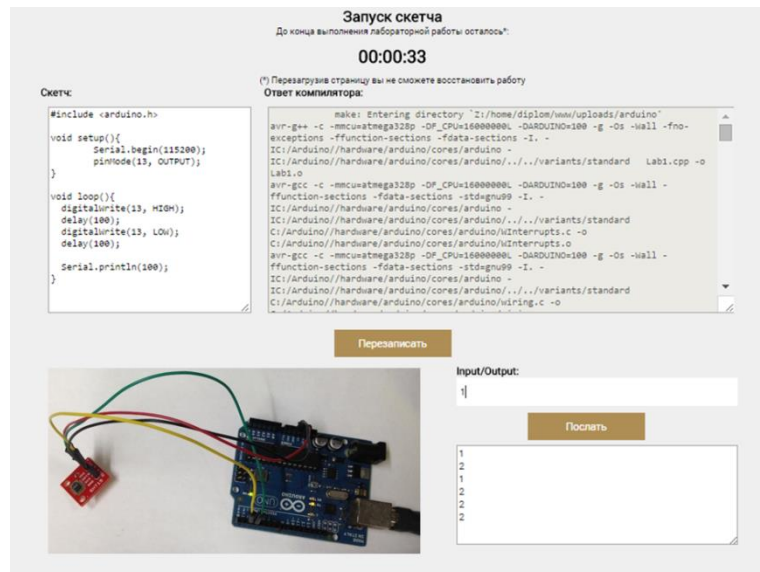
Figure 1: The result of running remote lab work R-Lab with supervision of the process using a webcam

When using the developed PMC, a student develops a program (sketch) for Arduino Uno either directly on a web-page or in the sketch development environment of Arduino Software (IDE) [7] and then transfers the sketch to the web-page. After that, the web-server compiles the sketch displaying the results on the web-page in a browser. If compilation is successful, the program is loaded into the microcontroller. According to team member's instruction the running of the sketch begins, and the results are transmitted to the user via a web camera. Monitoring of the result of programming is fulfilled by means of real-time web-camera broadcasting of the appearance of the printed circuit board with external devices.

To extend the functionality of the software associated with the access control to software tools and equipment, as well as registration of students' results, it is advisable to use an LMS-system [1-3]. One of such systems is the MOODLE [8], which has been selected for use at our university for a number of reasons. Specifically, this LMS provides the mod_ejsapp module [9], which ensures the ability to run and use software models as virtual and remote lab works, developed with the help of such a powerful development tool like Easy Java/Javascript Simulations (EJS) [10-11]. It is designed for rapid development of simulation systems and remote control. During the development of the software system, not only its integration with the module for the MOODLE is provided, but also with external applications, such as LabView and Matlab/Simulink, which allows organization of remote training and research laboratories [9].

With assistance of EJS a PMC was designed for R-Lab, which allows studying air flow in a pipeline and implements its supply control (authors – Master degree students R. Gridchin and S. Potemkin). The scheme of process control automated system is shown in Fig. 2. The air flow is created by a fan mounted to one pipeline end. The second fan is also mounted to the other end, thus it is used as an air flow sensor. A valve is installed into the pipe, the angle of rotation of which changes the air flow. Control of fan actuators and dampers, as well as sensor data output and processing, is realized using Arduino Uno controller. Students' work with the R-Lab is provided by means of LMS MOODLE and a software module, developed in EJS.

The upper level of PMC of this laboratory complex is represented by the server containing LMS. The main function of the top-level PMC in this case is transmission of control signals from the client side (browser of the student performing laboratory work) to lower levels of the complex and transfer of the collected and processed information using ES to client via the Internet. Physical object control system is based on Arduino Uno controller. Data transmission through the Internet is performed via LMS MOODLE and a software module developed in EJS.

There are a number of problems, which hamper automatic restoration of the object after lab work running. For example, during the study of destructive testing methods of mechanical properties of

materials after each experiment a sample requires replacement. In this case it is advisable to apply V-Lab technology.
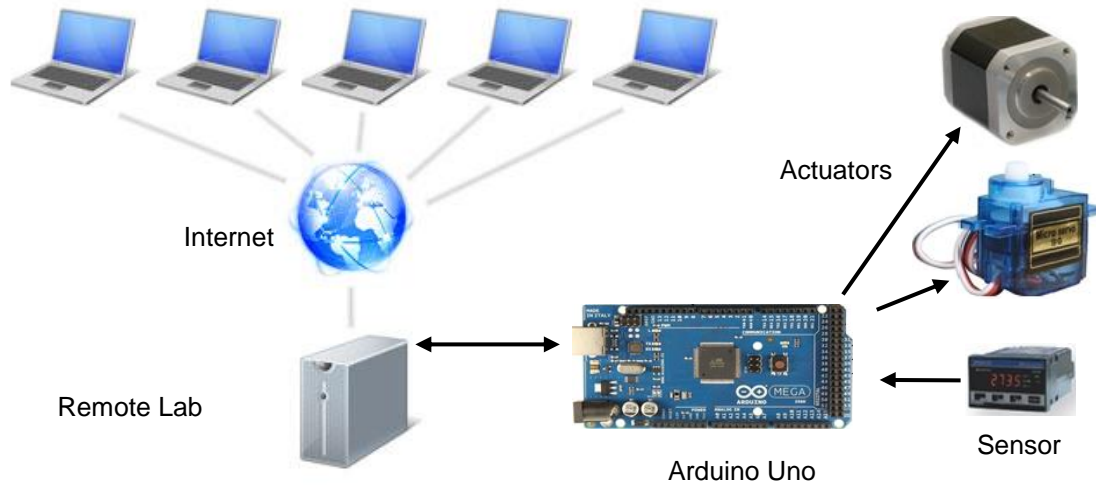

Figure 2: Laboratory complex pattern

This PMC is based on integration with a personal computer, thus the use of specialized software for 3D-models construction of physical devices and their behavior modeling is efficient. In particular, gaming systems can be used (game engine technology) to realize V-Lab, including Unity3D [12,13]. With the help of such software an object model can be built, as well as 3D-visualization and control of the facility via the Internet. In particular, the PMC is designed to perform virtual laboratory works on a sample stretching (author - student A. Portnyagin). The system allows to simulate the process of installation and stretching of a sample, shows a record of dependence on the degree of deformation forces, scales the image, changes the view of the testing machine during the research process. The results of the stages of the virtual lab, developed using Unity3D, are shown in Fig. 3.
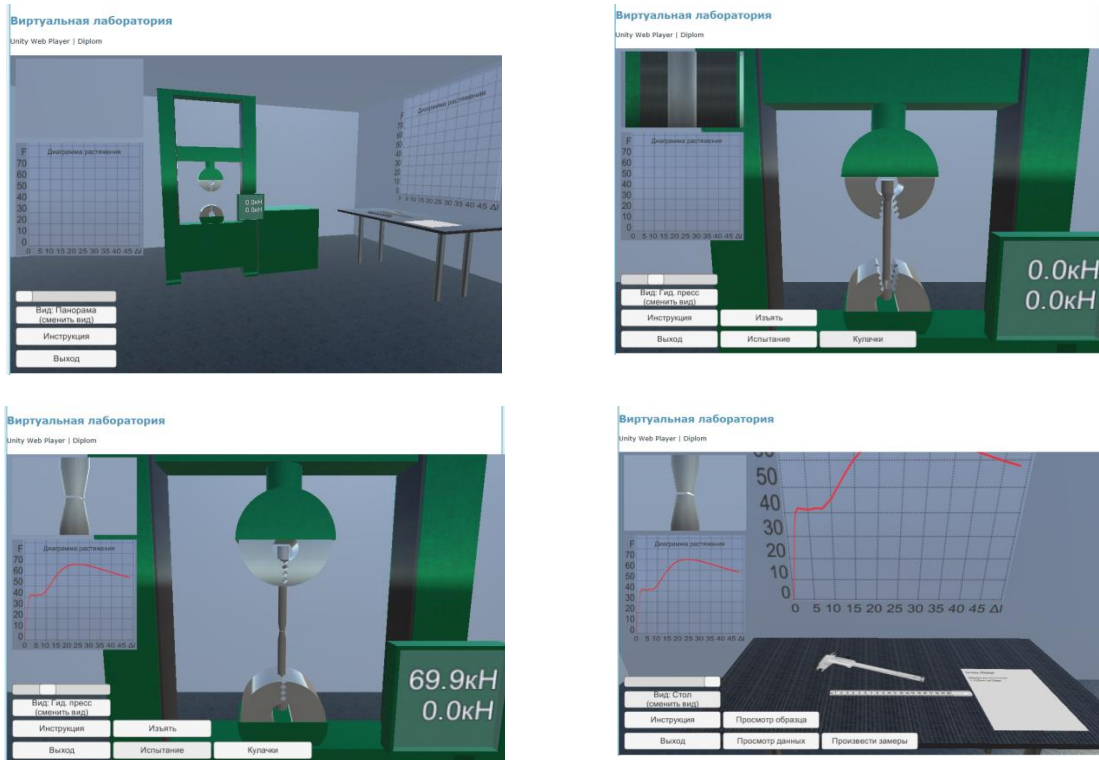

Figure 3: The results of the stages of V-Lab, developed using Unity3D

3 DISCUSSION

The above described issues of the development and application of remote lab and virtual lab technologies have been introduced into the educational process, thus improving its practical orientation. Application of Embedded Systems to the teaching of programming and control of technical facilities has improved students' motivation, because they used to work with physical objects. For students studying IT the diversity of the established software systems increased. Students of technical specialties created objects for control and studied the processes modeled by virtual lab. As a result of introduction of these technologies for three specialties the special disciplines' evaluation and evaluation of related subjects increased by 23 percent and by 16 percent respectively.

4 CONCLUSIONS

Analysis of remote and virtual labs developed by Master degree students shows that the proposed in this paper methodology of cooperative work of students on the development of programmed and methodological complexes for organization of V-Lab and/or R-Lab allows students in the course of academic work to solve complex challenges of design of complex mechatronic systems, as well as to study the technology of integration with specialized software systems and to master technologies of web application development. In general, development of a physical object of control or management, installation of drive actuators, development of control algorithms, integration with PCs and remote access using web-based technology is the basis for cooperative work of students of different specialties.

Acknowledgements

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