UDC 372.862

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Virtual Labs in Engineering Education

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The article deals with the use of virtual labs in engineering education. The programmes which allow simulation of electronic circuits and robotic systems have been considered. The analysis is based on the use of virtual labs in the distant course "Practical engineering education" for pupils. The programme is designed by the authors.

Key words: virtual laboratory, simulation, microcontrollers, circuits, robots.

Introduction

In spite of the growing labour market demands for engineers of new generation, among the applicants' preferences there is still a shift towards juridical, economic, and managerial specialities. Therefore, one of key tasks nowadays is to promote engineering education. This task is necessary to be resolved even at school level at the time when a pupil develops his/her preference for future profession.

Apart from programming taught as a part of informatics, there is a lack of engineering subjects in the school curricula that causes the situation when applicants are not prepared for engineering study at university, which leads to the decrease in students' academic performance, growth of expulsions and transfers to humanity departments [1]. Therefore, low level of pupils' engineering knowledge decreases popularity of engineering jobs, as the applicants do not want to enter and study at engineering universities.

All these condition the urgency of developing supplementary educational programmes for practice-oriented research-engineering clubs of engineering art for senior pupils and junior students aimed at involvement of youth in the engineering creativity, development of engineering thinking, and, as a consequence, motivation of choosing engineering profession.

Nowadays, diverse online courses have gained great popularity, as they provide an opportunity of learning at home, at any time, with the playback option learning material repeatedly. Such courses enable to acquire the necessary skills at minimal cost for the students simultaneously developing necessary competencies. However, with regard to the issue of engineering education, there is a problem of lack of necessary equipment. Courses of engineering art, particularly if it involves electrical engineering and robot design, are senseless without practical classes, which, in their turn, require special laboratory equipment. How, for example, to learn to design robots without necessary materials?

To solve this problem, one can use a virtual laboratory. They allow emulation of practical tasks to draw a circuit, programme a microcontroller, and even design and programme robots with high degree of confidence.

The present article gives the review of contemporary learning techniques and considers their application in full-time and distance courses on engineering design. The review is based on the authors' experience gained in designing the distance course "Bases of practical engineering modeling" intended for pupils in the course of the state project of the RF Ministry of Science to arrange practice-oriented research-engineering communities of engineering art.

Simulating electronic microprocessor-controlled circuits

Using microcontrollers in electronic circuits ensures the sufficient increase in solution flexibility and decrease in its design

complexity, hence, its cost. This fact served as a starting point in wide application of microcontrollers in the field of electronics. For example, even such a simple device as a lantern can be microprocessor-controlled. Therefore, the issue of learning electronic circuit development is now closely connected with the problem of microprocessor application.

As far as the authors know, at present there is only one free system, i.e. virtual laboratory for simulating electronic circuits controlled by microprocessor. This is an online service circuits.io [2] (fig. 1).

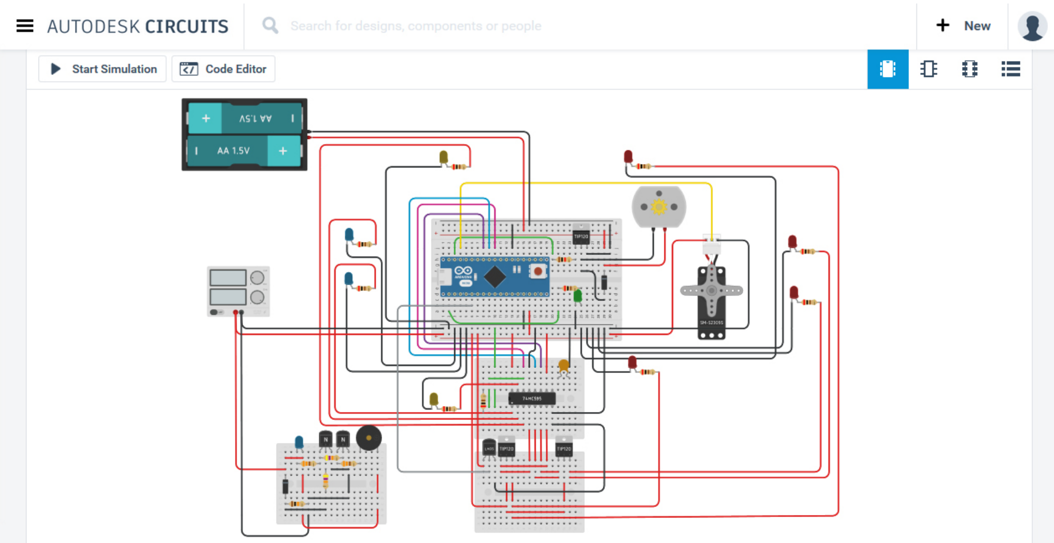
As this system functions on-line, its application does not imply installation of additional software – all operations are performed directly in browser. It should also be noted that software is well compatible with old computers (e,g., the software was successfully tested by the authors using notebook with Intel Core i3 380M processor produced in 2010). Hence, one can say that the software is highly accessible.

The virtual laboratory allows for development of electronic circuits using a wide set of components including current and voltage sources, passive components (resistors, condensers, and inductors) and active components, such as diodes, transistors, operating amplifiers, micrologic units, various sensors, and displays. In addition, the interface of user's operation with components is fully supported, as one can turn a potentiometer during simulated circuit operation, which results in alteration of its resistance and is taken into consideration in model operation; change the temperature, which is measured by temperature sensor etc.

The primary mode of designing electronic circuits is a breadboard mode, at which the components are arranged and connected. There is also a view mode (without editing) of principal electrical circuit, which is automatically composed with connection to breadboard. Besides, editor board is provided to trace printed circuit board and export the result of the standard Gerber format supported by nearly all printed circuit board equipment.

However, the highlight of circuits.io environment is an emulation support for microprocessor control. The environment has Arduino board and Atmel microcontrollers as well as restores their programming instrument of Arduino board. Thus, students have an opportunity to develop electronic

Fig. 1. Virtual laboratory circuits.io



circuit, microcontroller programme, and model programme circuit interaction.

It should be noted that Arduino board is often criticized in professional community [3]. The experts mainly criticize the programming style of Arduino environment, which is not consistent with the industrial microcontroller software style and prevent from achieving maximum efficiency in using available resources.

Nevertheless, the authors suggest Arduino platform to be well suited for learning fundamentals of embedded system design, since comparatively low knowledge is required to obtain first practical results. This feature facilitates further study of more complicated development techniques.

To specify the problems of Arduino programming and show the ways of its development are the tasks which have to be taken into account in developing courses on circuits.io and Arduino environment.

The use of Arduino also allows students to easily turn from virtual experiment to practice – Arduino bound is cheap and does not require additional equipment except USB cable.

The disadvantage of circuits.io board is an absence of sensors with digital interface. Arduino model is fully supportive of i2C interface, whereas only other types of Arduino can be used as a device for connection. On the one hand, this option allows learning the operation of i2C bus in both master and slave modes. On the other hand, digital sensors are now widely used, but the lack of support reduces the scope of its functions that could be performed at the courses based on this board.

On the whole, it is necessary to underline that circuits.io service can efficiently be used to develop courses on circuits engineering and embedded system design, allowing the entire cycle of a unit design including development of electronic circuit, software debugging, and PC board layout.

Robot simulation

The capacity of circuits.io system is limited due to simulation of electric component – it can show how propeller is rotating on a motor or servodrive is rotating, but it does not provide simulation of their interaction with the physical environment. It is an exclusive province of other programmes intended for robotic system simulation.

Based on the preliminary analysis the authors have distinguished three existing systems that can be used in education as virtual laboratories: ROS, Webots, and V-REP.

ROS system

ROS (Robot Operation System) [4] is a platform to design robots, which was developed by the experts of Stanford University. It is the only fully free system with open source software among the three mentioned above. ROS system was developed as a core for implementing robotic software and, together with other components developed in this environment, such as Gazebo emulator [5], can be used as a virtual robotics laboratory.

The main disadvantage of ROS is that only specific versions of necessary software package can be installed in Ubuntu operating system. Numerous Internet sources considering this system describe its installation and solution of arising problems of environment and component compatibility. This solution cannot definitely be recommended for school online courses, as the most part of pupils are not able to install it.

Webots System

Webots design environment [6] was developed by Cyberbotics corporation founded by the experts of Federal Polytechnic School of Lasagna (EFPL). It is the most functional robot simulation system operating in Windows, Mac OS and Linux systems.

This system supports robot simulation and its interaction with the physical environment, allows designing robot control programmes in C++, Java and Python programming languages. The system includes a lot of robot models. The information on the system including electronic textbook Cyberbotics' Robot Curriculum [7] is widely accessible.

Unfortunately, all programme versions including educational one are commercial. Free evaluation license provides programme only within a month, after which only editing of two standard models is accessible, the rest can be opened in playback mode without modification. Such limitations make application of this system in online courses impossible.

V-REP System

V-REP system [8] is a commercial version by Coppelia Robotics corporation, but its license makes possible to use it in education for free without functional limitations. V-REP system is accessible for Windows, Mac OS, and Linux.

In spite of the fact that interface operability and documentation somewhat yield to Webots system, V-REP can be efficiently used as a virtual robotic engineering laboratory.

V-Rep is a virtual modeling environment with integrated design sevice, which allows building different robotic engineering devices: from manipulator to robots floating in the plane or in water-air environment, as well as simulating their behavior simulation. The library has a great number of previously designed robots, behavior of all units and components that can be set by means of scripts.

The principle shortcoming in using V-REP in online school course is the need to know Lua programming language which is not taught at school. In fact, the system supports integration with 7 programming languages: C, Java, Python, Matlab, Octave, Lua and Urbi. However, the system core operates with Lua language, hence, to use other programming languages undoubtedly requires writing small adaptor programme in this language. Therefore, designing course of practical engineering modeling for pupils the authors took the decision to add a small section of Lua programming. This programming language is similar enough to other contemporary programming languages. It is hoped that its sufficient learning does not make a big difficulty for students having experience in other language programming. Otherwise, one has to use a code fragment unclear for students and refuse integrated design environment that makes system operation more complicated.

Conclusion on robotic engineering design systems

The combination of compatibility with all common operating systems and free educational license makes V-REP the only accessible system applicable for online courses as a virtual laboratory.

However, if the system is used in courses held in an education institution having special software, one can recommend using Webots system as an environment with large potential and usability.

ROS environment can be recommended for using in university educational programmes. Available open source codes allow application of this system in learning and developing algorithms of computer vision, inverse kinematics, localization, and mapping. ROS system is widely used in modern research. However, its application may cause problems related to system administration including installation of strictly fixed versions of operating systems.

Testing

In the frame of the state project of the RF Ministry of Science to arrange practice-oriented research-engineering clubs, the authors have developed the distance course for pupils “Bases of practical engineering modeling” using simulating systems considered in the article. The course takes 40 hours and considers issues related to design of built-in and robotic engineering systems.

The first part of the course is concerned with designing microprocessor-controlled electronic circuits using circuits.io virtual laboratory. The second part of the course based on V-REP system deals with high-level programming issues of robot behavior. In this case the attention is paid to such questions as navigation, territory survey, collision detection and response, interaction with the environment.

Conclusion

The article reviews contemporary virtual laboratories that can be used in engineering education, for instance, designing online courses, where one of the key challenges is a need for expensive laboratory equipment. The systems for modeling electronic circuits and robotic engineering have been considered. The performed analysis is based on practical use of virtual laboratories in the course developed by the authors "Bases of practical engineering modeling" for pupils. It is shown that use of virtual laboratories allows pupils to learn the issues of robotic engineering system design without special equipment.

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UDC 378.147.88

Rewarding Learning of Maths in Engineering Schools: Laboratory Works

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The approach to development and use of laboratory works in training discrete mathematics and mathematical logic is suggested in the article. It is based on the computer tools to develop and improve productive thinking. The works involved are based on modeling subject field, they include target setting which determines students experimental and constructive activities as well as resources for automatical evaluation of partial solutions submitted by students. Experiment results have shown a significant increase in efficiency as compared to the multiple choice tests.

Key words: laboratory works, discrete mathematics, mathematical logic

Introduction

A laboratory work on discrete mathematics is often defined by most of contemporary authors as a set of problems on a definite subject aimed to develop students' certain skills. It seems to us that under such an approach, performance of laboratory work is no different from solution of individual home task or a set of tests [1-3].

Traditional engineering education interprets laboratory work on mathematics as a training session being a basic unit of laboratory (calculating) practice, using numerical techniques to solve professional problems [4]. However, the solution of routine problems relevant to their future job is a relatively rare case, they are mostly "professional" engineering problems often called the applied problems.

Laboratory practice is to consist of examples of problem solutions modelled on the basis of creative individual tasks. In this case laboratory tasks intensify students' independent work, contribute to better understanding of the subject and master their problem solution skills. In the classroom students take an active part in solution and analysis of the problems that they have to solve individually. Independent students' solution of the problems promotes their better understanding of the theory and develops their practical skills of managing the tasks that relate to studying the discipline "Discrete mathematics".

The training process will become more efficient if its participants solve non-trivial substantial problems and, for this purpose, they need to adopt new methods and tools including corresponding theory. Besides, the idea of learning process as a kind of research work increases the students' motivation.

Hence, laboratory work on discrete mathematics is a basis for acquiring research competency of future engineers.

It should be noted that the terms "laboratory work" and "laboratory practice" are often used in the literature as synonyms. These terms are better to be distinguished. The basic difference of laboratory practice from a laboratory work consists in systematic nature of the former. The practice includes several laboratory works different in subject and, sufficiently isolated in time of performance, but united by common goal relative to a student's specific training area.