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Development of Laboratory Courses for Specialized Remote Access Laboratory in iLab

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Abstract: This study proposes an approach to the development of laboratory research courses for industrial interfaces. The National Instruments Laboratory Complex and the iLab software by Massachusetts Institute of Technology are used as the material and technical base of the research which provide a platform to introduce students to the concept of virtual laboratories in general and to the use of industrial interfaces in particular. Using virtual and hybrid laboratories in the educational process will on the one hand enable the student to perform experiments with equipment and material, to gain practical skills in experiments conducting and to familiarize oneself in detail with a computer model of a unique object without the risk of costly equipment damage or bodily injury. On the other hand, the connection of existing laboratory equipment and devices via the Internet in a hybrid laboratory allows the laboratory activity to be moved to a new level, where multiple students might simultaneously conduct laboratory work remotely and have a more flexible schedule which would be hardly feasible in the traditional laboratory work.

Key words: Virtual laboratory researches, industrial interfaces, GPIB, remote access laboratories, e-learning, distance learning technologies

INTRODUCTION

Practical and laboratory courses play one of the most important role in the modern educational process. Often, the percentage of the acquired material depends not only on the quality of educational material but also on the way, the classes are given. Interactive teaching process allows for informative demonstration of the extent and nature of the influence of various physical parameters or the initial and boundary conditions in the study of mathematical models. Practical application of virtual laboratories has a significant impact on the students learning process and leads to improvement of its quality (Krasnynskiy *et al.*, 2010, 2011; Ostroukh *et al.*, 2011a; Ostroukh and Nikolaev, 2013; Churin *et al.*, 2011; Malygin *et al.*, 2007). Well-developed system of virtual laboratories substantially balances the lack of direct contact with laboratory equipment through the use of a wide range of virtual installations' or devices' options.

Being a virtual practical work, the educational system, just as any other software, is a set of different modules implemented using appropriate programming environments, editors and a set of supporting tools and utilities. When creating an educational system, it is desirable to use the universal design tools.

To accelerate the development, the specialized tools are used, such as ready-made tools for testing the knowledge or software declared by developers as environments specifically designed to create shared laboratories. A number of projects (including Russian) are noted for the convenience and easy to use. Many useful features save time when creating the relevant shared laboratories section. A set of provided tools in these programs may be used to develop practical courses based on object models to arrange various disciplines study (Ostroukh and Nikolaev, 2013; Vladimirovich *et al.*, 2013a; Petrova *et al.*, 2008).

APPLICATION OF LABORATORY PRACTICAL COURSES IN THE EDUCATIONAL PROCESS

Despite the fact that the training facilities are widely used in the educational process, they are auxiliary didactic tool. A teacher has the determining role in the conventional teaching. Communication between the teacher and the student is the basis of information transmission, an important feature of which is the presence of immediate feedback. However, from the earliest stages in the development of communication

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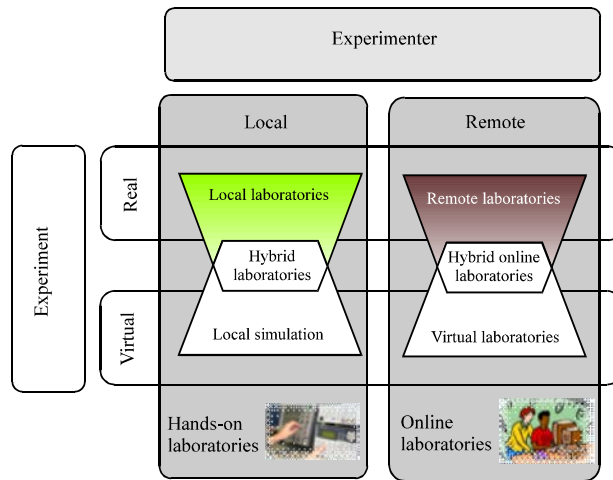State Technical University, MADI, Moscow, Russia
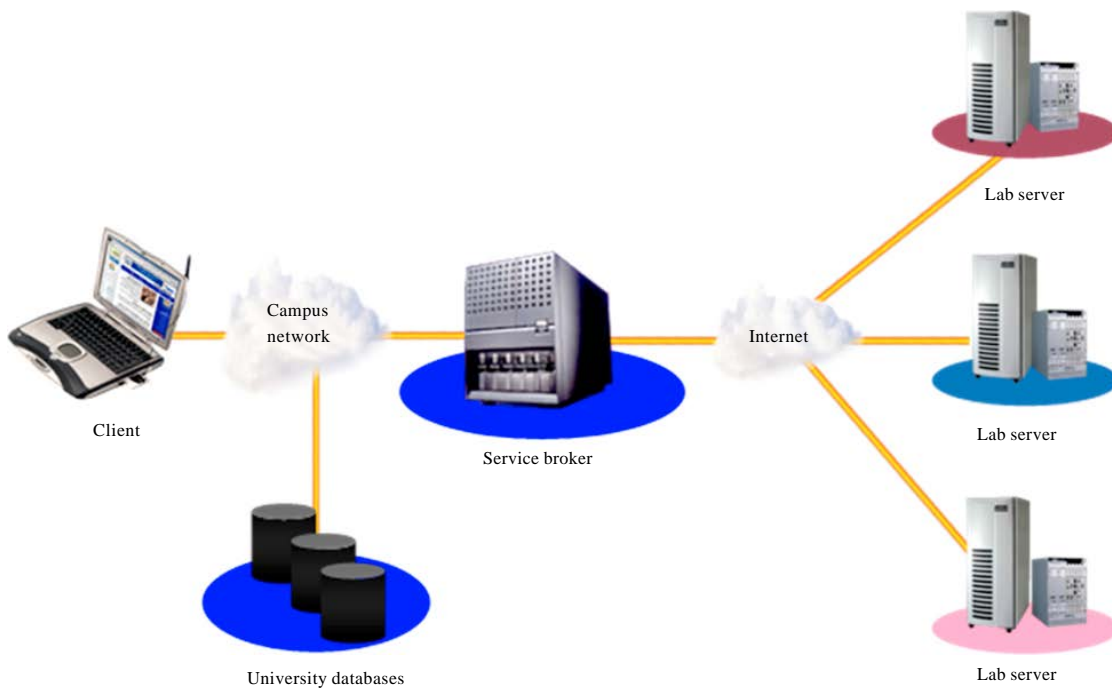
Fig. 1: Types of laboratories

Fig. 2: iLab shared architecture

tools, a mediated communication with time-spaced feedback is used in interpersonal relationships and that is the basis of distance learning.

You can select the following types of laboratories (Fig. 1):

Traditional = Involve working with highly specialized equipment and a computer with a physical presence of students

Virtual = Performed using software
Hybrid = Performed on real hardware via software interface

The iLab project is based on the following concept (Fig. 2). Online laboratories, i.e., laboratories with real equipment which are accessed via., the Internet, promote the development of science and engineering education, greatly expanding the range of experiments in which

students can participate during their training. Unlike traditional laboratories, access to online laboratories can be obtained not only in universities but also from all over the world.

The purpose of iLab is to simplify experiments both for students and the professional community as much as practical. The ultimate goal of the project is the creation of an extensive experimental base, the replenishment and use of which to be available worldwide.

Students conducting experiments gain the motivation which makes the learning more efficient. Experiments allow students to compare the real experiments with simulation, to work together and to find answers to their questions independently. Nevertheless, in many engineering classes no experimental installations are set up due to high costs, lack of space or for safety reasons. Providing online access to remote laboratories, iLab enables students to perform laboratory work, whatever remote location they may be in (Krasnynskiy *et al.*, 2011, 2012; Malygin *et al.*, 2007; Ostroukh and Nikolaev, 2013).

CONCEPT OF MADI ACS DEPARTMENT SOFTWARE AND METHODOLOGICAL SUPPORT INTEGRATION INTO ILAB ENVIRONMENT

In 2007 with the direct participation of the "Automated control systems" department, the Distance Learning Center was established (DLC MADI). The DLC MADI website (http://cdomadi.ru) provides Electronic Educational Resources (EER) for various academic disciplines and levels of education, developed based on modular and competency approach (Krasnynskiy *et al.*, 2012; Barinov *et al.*, 2012; Vladimirovich *et al.*, 2012a, b; Ismoilov *et al.*, 2013).

Implementation of the remote access laboratories concept should be based on the well-proven iLab service (Fig. 3).

The specified service has been deployed in 2012 by the faculty of the "Automated control systems" department, MADI. The necessary iLab service installation and configuration expertise was obtained due to cooperation with Carinthia University of Applied Sciences (city of Villach, Austria).

Results of the work shall be incorporated into the academic activity of the "Automated control systems" department on the subject "Automated information processing and management systems interfaces." Extension and development of laboratory courses on the subject "Computer networks and telecommunications," as well as other MADI disciplines is planned in the future.

Interactive teaching process allows for informative demonstration of the extent and nature of the influence of various physical parameters or the initial and boundary conditions in the study of mathematical models
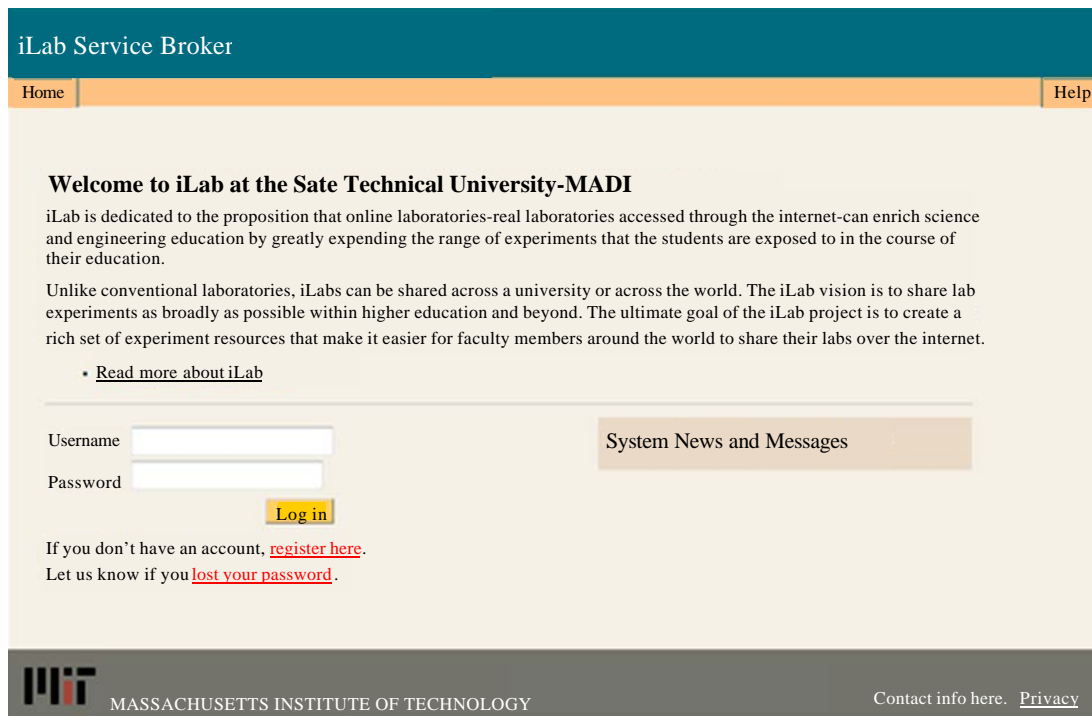
Fig. 3: iLab pilot project in MADI

(Krasnynskiy *et al.*, 2010, 2011, 2012; Ostroukh *et al.*, 2011a, b; Ostroukh, 2011; Churin *et al.*, 2011; Churin and Ostroukh, 2011; Malygin *et al.*, 2007; Ostroukh and Nikolaev, 2013; Vladimirovich *et al.*, 2013a, b, 2014; Petrova *et al.*, 2008; Barinov *et al.*, 2012; Vladimirovich and Evgenievna, 2011). Practical application of virtual laboratories has a significant impact on the students' learning process and leads to improvement of its quality. Studies support the conclusion that a well-developed system of virtual laboratories substantially balances the lack of direct contact with laboratory equipment through the use of a wide range of virtual installations' or devices' options.

Development and implementation of virtual laboratories moves teaching to a new level, significantly extending the range of educational problems and enriching them with contemporary content. Using virtual laboratories instead of the traditional ones shifts the emphasis in teaching from obtaining, processing and visual representation of experimental data to the intellectual domain of scientific analysis and the detailed interpretation of the results.

The principle underlying the concept of remote access laboratories has long been used in various fields of human activity, especially in science and technology. For example, devices and apparatus designed for the study of such objects which do not allow direct contact with a person for various reasons, have always been remotely controlled, particularly long before the advent of personal computers and computer networks.

In this case, the equipment remote control and remote experiments have been carried out with the aid of specially created devices that could send operator's commands to the desired distance by any available method at the time, a sequence of electrical signals through the connecting cables, by radio etc.

The advent and development of the Internet which led to a significant simplification of electronic communication and which gave the opportunity to easily connect any PC to another PC or a high-end server anywhere around the world, has made it possible to form and implement the concept of real laboratories equipment remote control. At the initial stage of its development, the concept meant only the integration in the learning process in the technical universities, including the distance learning system.

A trained user may perform the tasks of the university laboratory course using his/her personal computer, running the training equipment located in a university laboratory.

In the process of program implementation the following requirements are met:

- The developed electronic resources should be implemented in the SCORM standard
- The learning automation subsystems should take into account the need to support the SCORM standard
- The user interface of developed subsystems must comply with the system concept and visual style of the User Interface (UI)
- The developed subsystems must meet the requirements for user access rights adopted in the host system
- The learning automation subsystems should provide a reliable network transmission and storage of education results and statistics, taking into account the technical characteristics of the existing LAN, as well as using the latest storage and backup hardware
- The comprehensive protection, both hardware and software, against unauthorized access from outside the network, shall be provided in the local area network being part of the system

DESCRIPTION OF STANDARDIZED SOFTWARE MODULES FOR SHARED LABORATORY

During the analysis of a set of training systems and virtual laboratory courses, as well as their creation tools by the authors of this article, it was decided to design the software that would provide for configuring the shared laboratories based on ready-made modules to study various disciplines. The composition of these modules should include universal measuring unit (Ostroukh *et al.*, 2011a; Vladimirovich *et al.*, 2012a, b, 2013a, b, 2014; Petrova *et al.*, 2008; Krasnynskiy *et al.*, 2012; Barinov *et al.*, 2012; Ostroukh and Nikolaev, 2013; Vladimirovich and Evgenievna, 2011; Vladimirovich and Vladimorov, 2012; Ismoilov *et al.*, 2013). The objects connected to the unit can be operated through the information network. The developed software should be flexible enough to enable reconfiguration, modernization and conversion in accordance with the domain studied.

The structure of the software created by the authors is based on the principle of modularity, allowing the same unit to be applied for several disciplines (Fig. 4).

It is assumed that the same program package initially provided will be installed on all laboratory workstations and will be further reconfigured depending on the type of workstation (e.g., "student workplace," "teacher workplace") and the discipline studied. An exception is the software for data collection server, since this computer is connected to a set of researched objects and access to its settings is permitted only to specialists.
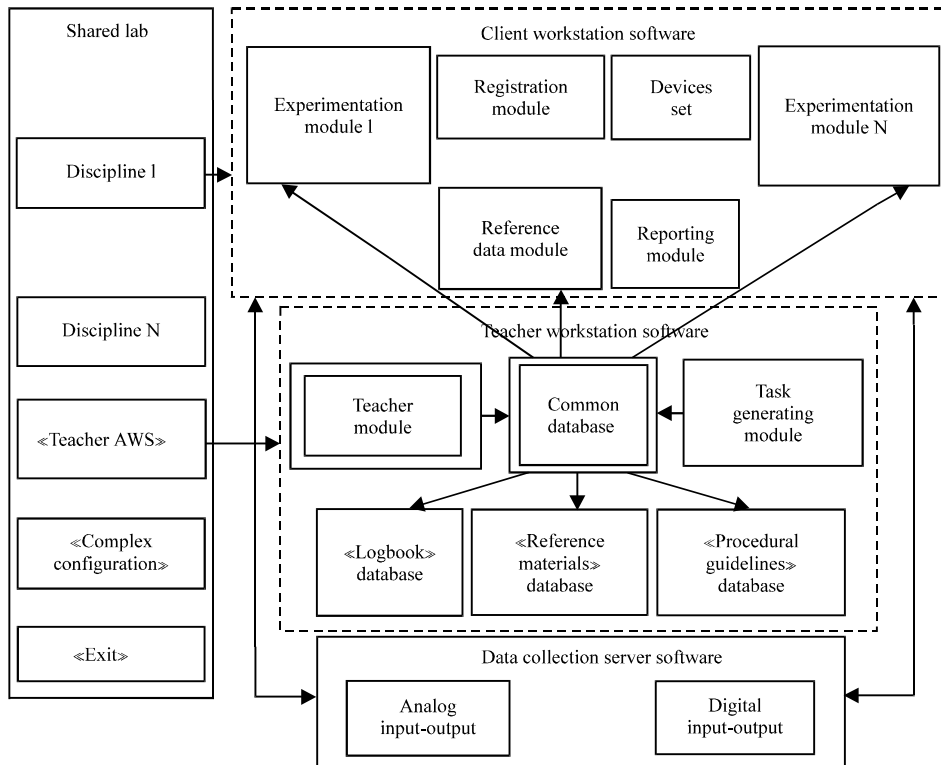
Fig. 4: Shared laboratory software overall organization chart

An example of structure for lab software modules created is shown in Fig. 4. In the first approximation, the structure can be divided into two major software blocks. The first block is the data collection server. This large separate module includes a basic engine for measuring physical quantities on a given object of research and for operations related to exercising certain effect on the object. It uses NI-DAQ drivers functions which allow to organize stress, strain, current, pulse and digital signals duration measuring via., adjustable virtual channels (Vladimirovich *et al.*, 2013a; Petrova *et al.*, 2008; Krasnynskiy *et al.*, 2012; Barinov *et al.*, 2012; Ostroukh and Nikolaev, 2013). The measurement results are easily transferred for further processing.

Inside the data collection module, the submodules responsible for I/O type (analog or digital) are implemented. This is provided in consideration of the fact that different types of I/O operations imply different principles of the data collection device operation. When creating and adjusting the described module it allows focusing on the implementation of the particular I/O type operations, without being distracted by other stages of development. Such a division presumes the use of the program with different device models. For example, if a digital chip is used as an object of research and the

hardware may not include I/O board with analog channels, then buying a reasonably priced digital module will suffice. This facilitates the software developer's complex set formation and creates preconditions for a finer configuration for a specific device. All this allows for creation of such an application for data collection server which is able to operate on the basis of various models of I/O modules and simultaneously perform measurements on several objects of research.

The second large block centralizes all submodules responsible for the execution of laboratory work and formation of practical skills in certain disciplines, automation of control functions and obtaining the reference and information data. For each discipline a universal set of software modules is assumed, the composition of which may vary due to the nature of the studied domain. The following general composition of programs can be distinguished in the structure shown in Fig. 4:

- "Registration Module" allows a registration of a subgroup of students to perform the selected laboratory work, obtain access and the text of the task variant from the teacher
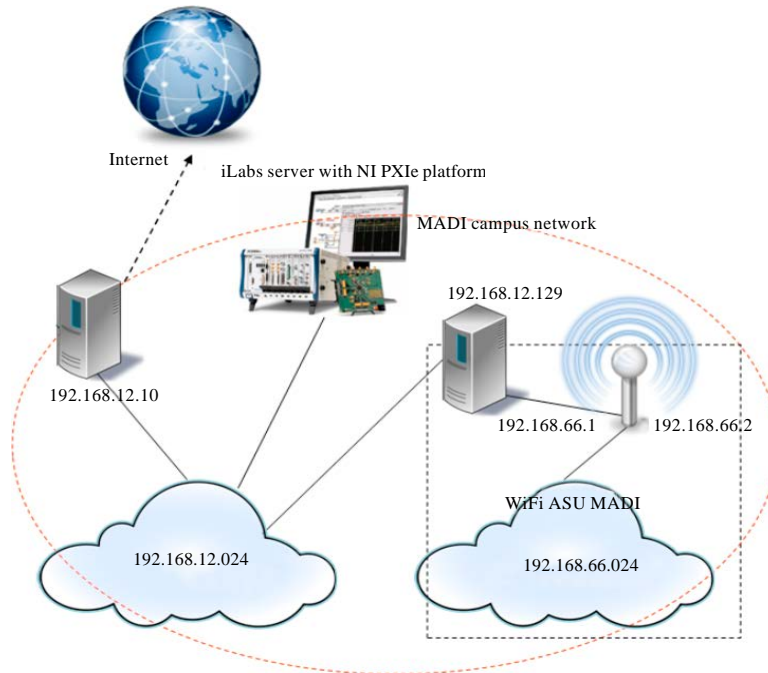

network. This network includes classroom computers, a router connecting the Department LAN and the Institution network, domain controllers, file server and a wireless router with IP-address 192.168.12.129. In 192.168.66.0/24 wireless network, this router has IP-address 192.168.66.1. The IP-address of the access point is 192.168.66.2. Laboratory installation on PXIe platform that is running iLabs server is connected to the wired network, so the access will be provided both from the local network and if desired, from the Internet.

SOFTWARE IMPLEMENTATION OF LABORATORY PRACTICAL COURSES (WITH EXAMPLE OF GPIB INTERFACE LAB RESEARCH)

The main window of the user interface is as shown in Fig. 6. The right pane displays the purpose of the lab work, as well as a brief description and the order of work execution.

The upper part of the window contains address of the receiving device "Listener." The program automatically generates the numbers to be sent. These numbers are displayed in the field "Number transmitted" in the upper part of the window.

The left pane of the lab work window consists of three parts (Fig. 7):

- Signal parameters
- GPIB commands for the NI instrument simulator
- Diagram

NI instrument simulator is used to demonstrate the commands which is configured as a signal generator. To generate signals indicate the parameters of generated signals:

- Signal type
- Signal amplitude
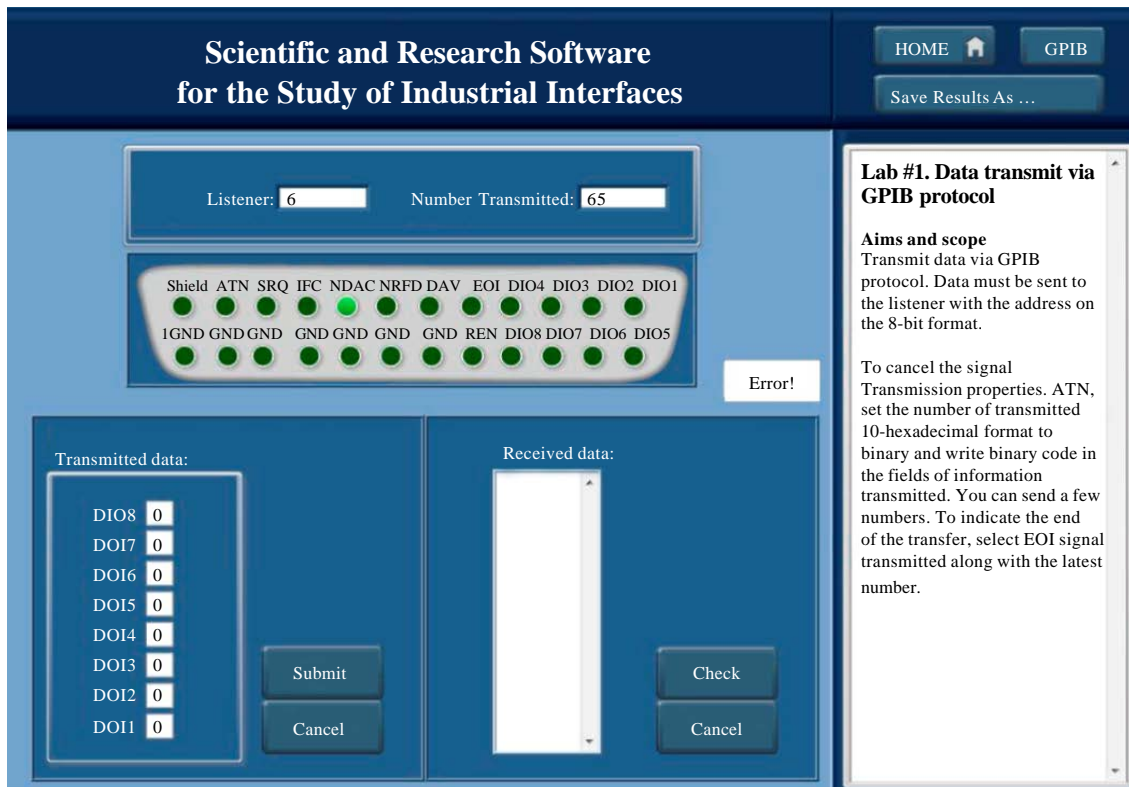- Signal frequency
- Pulse ratio (for square wave signals)

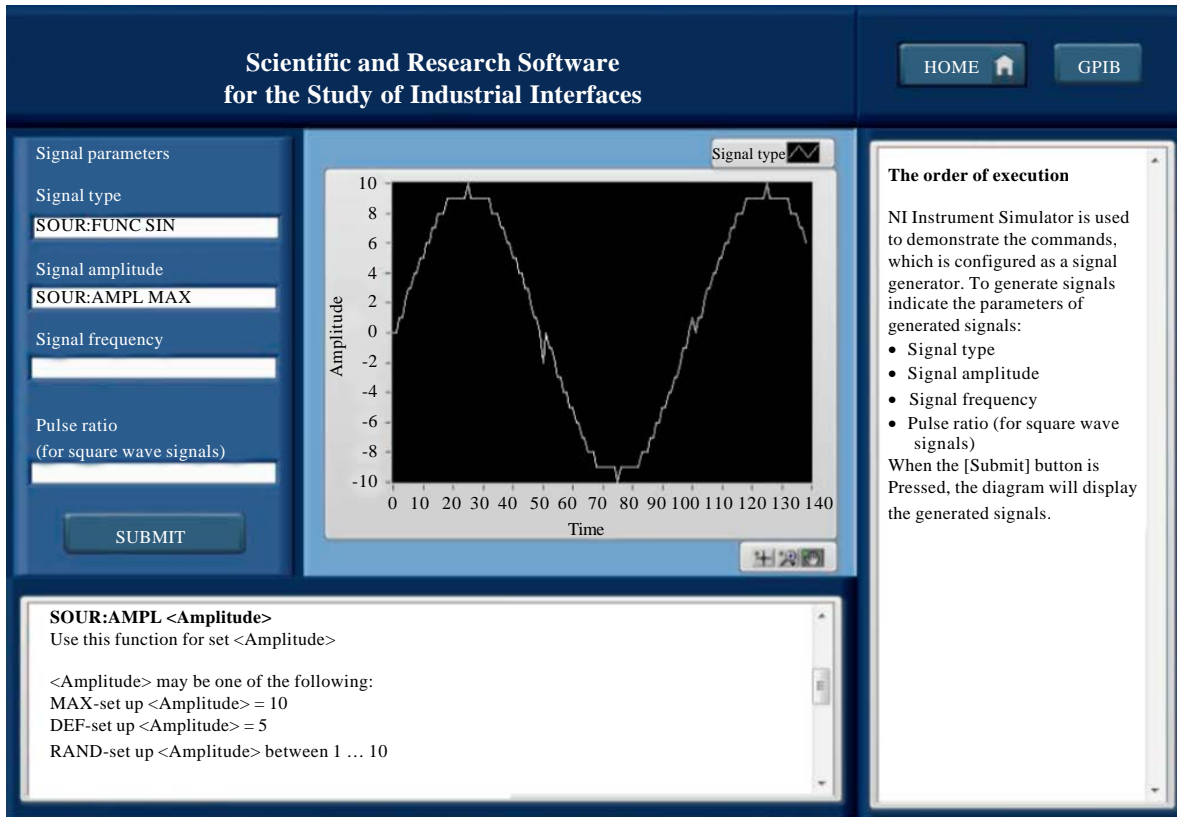

Fig. 6: GPIB interface lab research

Fig. 7: Generated signal

Table 1: Parameters of generated signals

Signals	Description
To change the signal type (shape): SOUR:FUNC	
SIN	Sinusoidal signal
SQU	Square wave signal
NOIS	Noisy sinusoidal signal
RAND	Arbitrary signal
To set the signal amplitude: SOUR:AMPL	
MAX	Setting amplitude 10
DEF	Setting amplitude 5
RAND	Setting arbitrary amplitude 1-10
To set the signal frequency: SOUR:FREQ	
MIN	Setting the frequency 1 Hz
MAX	Setting the frequency 20 Hz
DEF	Setting the frequency 10 Hz
RAND	Setting the arbitrary frequency 1-20 Hz
To set the square wave signal pulse ratio: SOUR:FUNC:SQU:DCYC	
MIN	Setting the pulse ratio 20
MAX	Setting the pulse ratio 80
DEF	Setting the pulse ratio 50
RAND	Setting the arbitrary pulse ratio 20-80

To do this, use the commands listed in the Table 1.

When the [Submit] button is pressed, the diagram will display the generated signal (Fig. 7).

CONCLUSION

Creation of the smart integrated online laboratory for engineering disciplines based on software for data collection, analysis, processing and visualization systems-LabVIEW (Laboratory Virtual Instrument Engineering Workbench) significantly increases the efficiency of the educational process in engineering disciplines.

Integration of hardware, software and methodology and technology support that are well-developed and actually used in the educational process, for the purpose of creating online laboratories with distributed educational platform making use of the education standard remote control system, as well as multimedia computer simulators and heterogeneous testing system will improve the availability and quality of education while reducing training costs.

Inclusion of multi-role gaming and the related decision support systems in the general contour will, for the first time ever, allow creation of a unique smart

integrated online laboratory practical course for distributed e-learning in the engineering fields of study.

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