REMOTE ENGINEERING LABORATORY EXPERIMENTS FOR DISTANCE LEARNING CONCEPTS IN COVID-19 CONDITIONS

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Abstract

In the new conditions caused by novel coronavirus COVID-19 (SARS-CoV-2), teaching methods changed significantly. Most university teaching geared towards the online teaching process, which showed great changes in both teachers and students. One of the most difficult tasks was to create laboratory experiments that can provide good and sufficient knowledge in the first place, and to be control remotely from students' homes due to risks caused by virus. This paper presents several remote laboratory experiments controlled by CEyeClon viewer from Faculty of Technical Sciences Čačak, University of Kragujevac, Serbia. All experiments are included in teaching modules with suitable documentation for distance learning and provide practical engineering knowledge and skills. Experiments can cover a wide range of scientific disciplines.

Keywords: COVID-19, remote experiments, CEyeClon, distance learning, engineering knowledge.

INTRODUCTION

It was very challenging task to organize new form of classroom in the conditions of a pandemic caused by COVID-19 virus for all teachers and students. In some segments of education process, online teaching modules existed before pandemic, so for those teachers and students the transition to online teaching was to a certain extent easy. If the focus is on electrical engineers, most problem was to represent theoretical knowledge through practical concepts. Before pandemic, that task was much easier; laboratories were open for every student. Besides laboratories, internships in firms and industrial plants were also available. In certain manner, online remote laboratories gave solutions that can compensate practical knowledge [1,2].

Faculty of Technical Sciences Čačak provided many laboratory experiments before pandemic through project "Network of Remote Labs – NeReLa" [3] that provided excellent support for creating remote experimentation in pandemic conditions. Some experiments remained the same, unchanged, while a number of experiments were upgraded, but also new experiments were created according to new requirements. All experiments can be remotely controlled through CEyeClon viewer, platform created in Swiss laboratory. CEyeClon platform is organized like remote desktop platform with lots of possibilities like IP camera integration or scheduling time for a user access, etc. Every user access to experiment with suitable access key [4]. One of the great advantage is that lot of experiments can be set on just one PC with virtual machines. In this case, hardware resources are saved.

In this paper, three remote experiments were presented. All experiments can provide practical knowledge in different scientific areas, so it can be mentioned that experiments are multidisciplinary. Experiments are included in teaching curricula of several subjects. Students can do all laboratory assignments from their homes. Accompanying instructions and required literature were included in the platform. Some experiments provide report at the end of session, which can be automatically sent to e-mail.

RELATED WORK

Before online platforms for remote control of experiment in this particular manner, teachers struggled with the problem how to allow students to do some assignments from their home without laboratory equipment. The

easiest way was to create control of experiments through remote desktop and to observe everything with the camera. In this way, problems, like data protection or access restriction, are very pronounced. National instruments company created web-server in LabVIEW software called web publishing tool [5,6] where application created in LabVIEW can be controlled remotely through web browser. One problem in this way is that distance computer needs some additional plugins. Second problem is that all experiments created in this manner are limited to LabVIEW software, which is not cheap.

Few platforms, that allow students free access during pandemic, were active way before. WebLab-Deusto is active since 2000s and provides experiential learning by the use and development of remote laboratories [7]. It is created at University of Deusto and the most interesting experiment is Visir (Virtual Instrument Systems In Reality) - remote laboratory which supports remote experimentation with real electronic circuits. Another online laboratory set up called LabsLand provides real laboratory experiments (not simulations) in different fields: biology, chemistry, electronic, robotics, physics, etc [8]. Very important to mention is that all experiments are selected by educational levels: elementary, high school, middle school, university and college.

The developed platform for remote real-time control of Internet-connected system [9] is based on an industry-standard DSP board supported by Matlab/Simulink. Devices are controlled with Simulink code or M-code from Matlab.

REMOTE EXPERIMENTS

In the next paragraphs, three remote experiment will be presented.

Electronics - Non-inverting and inverting amplifiers

First experiment is simulation of non-inverting and inverting amplifiers that can help students at the beginning of their theoretical electronic knowledge. Figure 1 presents simulation of non-inverting amp. By selection of resistors values (R1 and R2) and values of positive and negative supplying voltage, output voltage can be calculated and presented

as a waveform in a graph diagram. Both input and output voltages are in phase. The experiment also contains a brief description of how the gain is calculated [10]. In the case that input voltage value will be multiplied with amplification exceeding range of the supplying voltages, sine wave of output voltage (amplitude) will be cut off and indicators will warn user about it (see Fig. 2) [10].
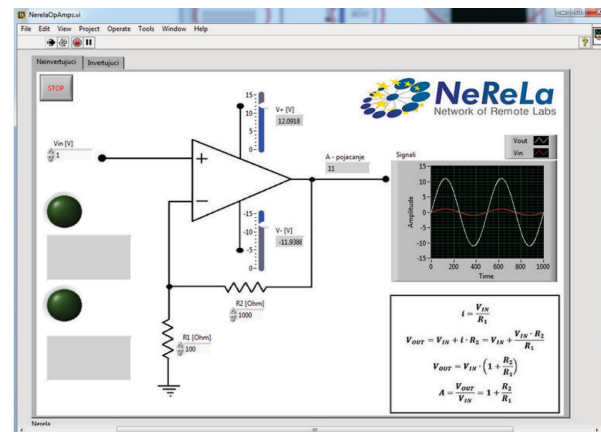

Fig. 1. *Application of non-inverting amplifier in progress*

Similar experiment is presented in the Figure 2, where input and output voltages are not in phase (the input voltage is applied to the inverting input of amplifier) and amplitude of output voltage is cut off [10].
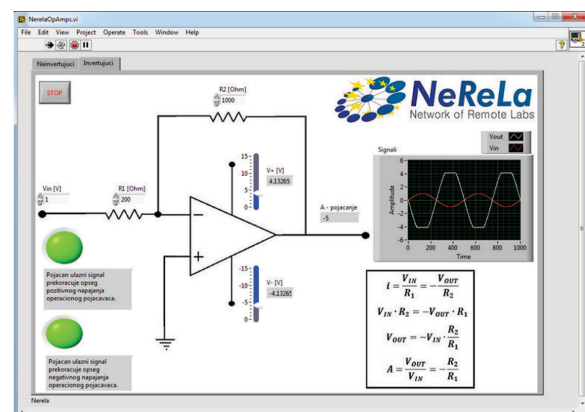

Fig. 2. *Application of inverting amplifier in progress*

Both experiments can be control through CEyeClon viewer or directly through web browser with LabVIEW web publishing tool.

Digital signal processing - Adaptive filtering laboratory

Students who are attending master courses need higher level of knowledge. In that manner, some topics in advanced DSP courses

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are related to adaptive algorithms. These algorithms are widespread nowadays, and they can be used for: unknown system identification, echo cancelation, filtering of signals in biomedical engineering, etc [11]. In this case, laboratory for unknown system identification is created. LMS (Least Mean Squares) and RLS (Recursive Least Squares) are two main adaptive algorithms that are used most often [11]. Application for unknown system identification uses LMS algorithm. Starting window of application through CEyeClon viewer is presented in the Figure 3.
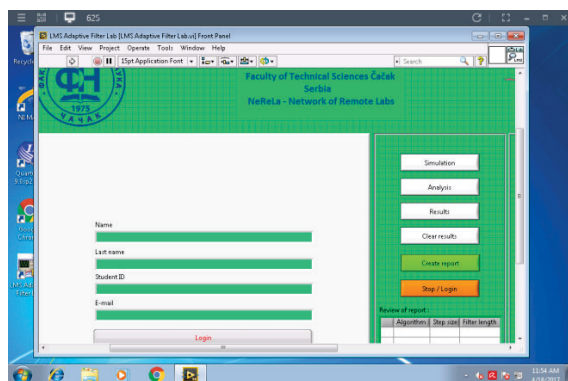
Fig. 3. CEyeClon viewer starting window for unknown system identification

In the beginning, student needs to enter some information: name, last name, student ID, e-mail (see Fig. 3) and after that application can be started. Student can specify input signal, unknown system impulse response and type of adaptive algorithm. This part of the task can be left with default parameters. It depends what student's assignment is in the first place. After that, LMS algorithm can be set: step size, order of the filter and adaptation speed. When student finishes all adjustments according to task, he or she can check results on the graphs. If the results are good, report can be created. Report will be automatically sent to e-mail that student specified at the beginning but also it will be saved on server PC where teacher can do review after the session. Final report is presented in the Figure 4.

Report consists student's information, time and date when the experiment was done and also graphs and tables of the experiment. First graph (left) in the report represents learning curve of LMS algorithm. Second graph (upper right) represents the coefficients of unknown system and coefficients of adaptive filter.

These coefficients remain unchanged (after the certain time) which means that adaptive algorithm identified coefficients of unknown system. Third graph (down right) represents error signal. In the begging error signal has some amplitude but after a while this amplitude is decreasing. When algorithm identified coefficients of unknown system, amplitude of error signal is almost zero. Table contains type of selected adaptive algorithm, step size and filter length.
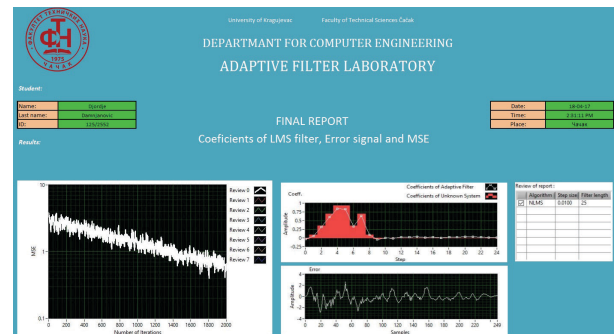

Fig. 4. Created report for unknown system identification

Remote control - Arduino Uno with 6 modules

Arduino Uno is a microcontroller board based on the ATmega328P microchip [12]. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button [12]. Figure 5 presents Arduino Uno board.
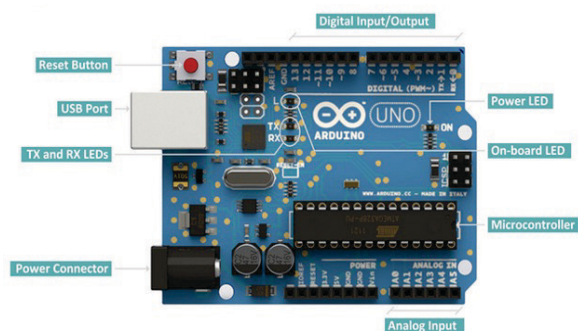

Fig. 5. Arduino Uno board

Arduino Uno is very easy to use and always interesting to bachelor and master students. In this case this microcontroller is used for subject Remote control, where Arduino is connected to 5 modules: light sensor (BH1750), infrared motion detection sensor (PIR), temperature and humidity sensor (2 in 1 sensor - DHT11), step motor (28BYJ-48) with

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driver (ULN2003). Scheme of connected modules on Arduino Uno is presented in the Figure 6.
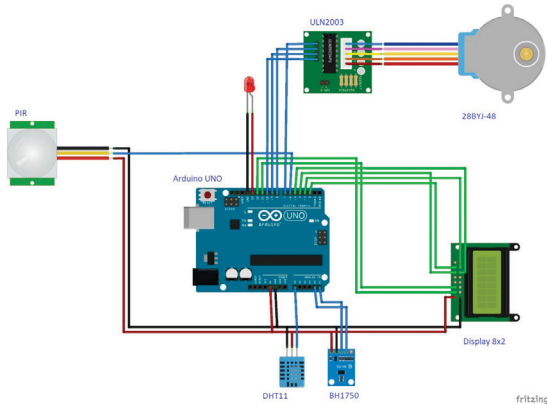

Fig. 6. *Scheme of connected modules on Arduino Uno*

When student is connected on CEyeClon viewer, Arduino Software (IDE) can be started. In this software student writes code for controlling of each module separately. If the code is compiled without errors, Arduino Uno will control module for that case scenario. Example of programing infrared motion detection sensor in Arduino Software (IDE) is presented in the Figure 7.

Fig. 7. *Programing in Arduino Software (IDE)*

Student can see through camera results of the current task. For example, Figures 8 and 9 represent successfully completed task for modules: temperature and humidity sensor and infrared motion detection sensor, respectively.
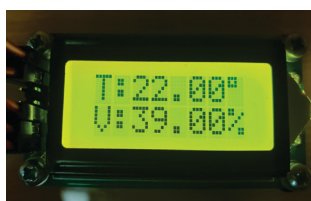

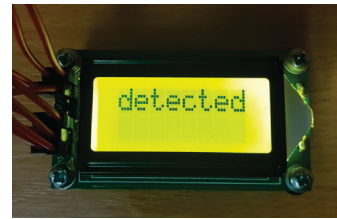**Fig. 8.** *Results of controlling temperature and humidity sensor*

Fig. 9. *Results of controlling infrared motion detection sensor*

This type of experiment is very interesting to students, because of the usage of real hardware in real time. Whole hardware through camera is presented in the Figure 10.
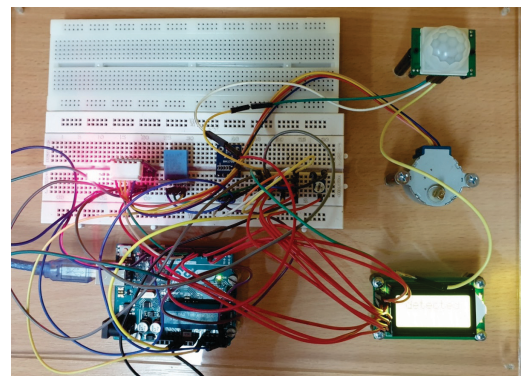

Fig. 10. *Experiment set up – view through camera*

CONCLUSION

Online experimentation has large impact at the faculties all over the world. Pandemic, caused with COVID-19 virus, contributed for increased use of remote online laboratories in scientific fields where practical knowledge is necessary. In this case, students do not need to visit laboratories at their faculties, they can access them from their home using only PC and internet.

Three remote experiments are presented in this paper. They can cover more than three subjects on bachelor and master studies. All experiments are controlled with CEyeClon platform, which basically presents upgraded version of remote desktop, with additional options (IP camera, scheduling time for a user access, etc). For access to specific experiment, student needs to install CEyeClon viewer and enter access key.

Beside these three experiments, Faculty of Technical Sciences Čačak developed many other remote experiments. In the future, plan is to cover subjects that do not have remote experiments yet.

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