

Blended Learning of DSP Through the Integration of On-Site and Remote Experiments

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Abstract - The aim of this paper is to describe blended learning of an engineering master course in DSP through the integration of on-site and remote lab experiments. This integration of lab experiments is suggested as one of successful solution for “visualization” of DSP theory. The student survey concerning to preferred type of lab exercises is carried out and results discussed.

Key words - DSP course, on-site experiments, remote experiments, blended learning mode

1. Introduction

As a rule, learning basic theoretical concepts of signal and system analysis and synthesis is difficult for the students of engineering. This difficulty is a result of the gap between understanding mathematical formalisms of these concepts and student’s abilities to connect these theoretical concepts with practical engineering applications. In the aim of solving this problem many “recipes” suggested for “visualization” of digital signal processing (DSP) theory.

There are many research papers dealing with on-site and remote engineering laboratory experiments. The most of these experiments designed by using LabVIEW and MATLAB/SIMULINK® environments. Some of them consider on-site and remote experiments from the engineering aspect primarily, whereas the other ones deal also with the educational aspect of this method of engineering education.

The five similar scenarios of building a remote web-based laboratory for development and running of DSP experiments are described in the papers [1], [2], [3], [4] and [5]. Laboratory hardware and software consist of microcontroller, digital signal processor (DSP), field-programmable gate array

(FPGA), LabVIEW Virtual Instruments (VI) and client application by which the end user (students) facilitates access to remote experiment resources. Students at remote terminals can perform remotely experiments using real hardware equipments and tools. An in-house developed embedded hardware and a software control system based on MATLAB/Simulink and LabVIEW is used in the DSP remote laboratory at the University of Maribor [5]. This remote laboratory enables the users to easily interact with a set of experiments through a friendly LabVIEW user interface. In addition, this remote laboratory includes a booking system, which enables remote users to book experiments in advance.

Some another papers that we analyzed [6], [7] and [8], deal with remote control applications.

The developed platform for remote real-time control of Internet-connected system [6] is based on an industry-standard DSP board supported by MATLAB/SIMULINK®. The control algorithms for the physical devices can be programmed by two different ways: (1) locally from SIMULINK® and (2) either locally or remotely from an M-code program which is installed from the MATLAB® workspace.

The framework for the WebLab laboratory exercise [7] has been designed using LabVIEW by creating flexible and scalable measurement and control applications that will enable a remote user to perform the required laboratory exercises and control the laboratory equipment.

Web based remote microcontroller laboratory is presented in the [8] as a possibility for making microcontroller experiments independent from the time and place. Several application modules, selected from real life applications, are designed to improve

the skill of the students. The system prompts students for user ID and password. The one who enters to the system will be the moderator of the experiment and 10 minutes duration will be assigned for experiment and the other users can only observe the experiment and discuss with others by using the chat tool.

The special issue of the International Journal of Online Engineering includes some works of The International Conference Exp.at'11[9] devoted to online experimentation, had as scope to contribute to the world capabilities in online experimentation and in particular in remote and virtual labs, fostering the collaborative work in emergent technologies Conference. The papers [10] – [14] have drawn our particular attention.

The approach suggested in [15], based on integrating on-site and distance learning environments, is similar to our approach of DSP laboratory. According to this approach, the students will combine, during the DSP lab, on-site lab sessions and remote-controlled experimentation. Such integration of on-site learning with remote-access experimentation offers a powerful tool, especially for students with learning disabilities or for students who are employed. Presented The Integrated Learning Methodology (ILM) offers an answer to the disadvantages of the on-site and web-based (virtual or remote-access) learning methods when used separately, by integrating their advantages. The laboratory administrator creates accounts and defines time quotas for each experiment. All users, including instructors, gain access to the system via Experiment Management System (EMS) that allows inputting User ID and Password in order to obtain an authentication and clearance to start the session. After clearance is granted and the student has requested a particular experiment, he is obliged to submit a preliminary questionnaire of the experiment, which is intended for checking that the student has sufficient knowledge for the experiment. The preliminary report is checked by the responsible instructor and, if it is successful, the student is allowed to allocate a time quota for the experiment. After performing the experiment the student submits the final report and gets score and remarks for the experiment.

As we intended to create a blended learning mode of our advanced DSP course on the basis of a mixture of

on-site and remote exercises and web-based teaching materials, the study of the papers [16] and [17] helped us a lot. In the paper [16] authors have described the usage of the remote laboratory in an e-learning scenario based on common learning platforms such as Moodle. The laboratory architecture is organized in three layers: the resources, the server and the user interface. The resources are the real electronic devices and software packages used to run the lab activities. The lab server is the software module that interacts with these resources and manages the incoming requests from end-users. The DSP lab is structured as a software development environment where users can develop and build C applications, and monitor their execution on the remote development board. Students are able to access the laboratory through a web interface. A proper scheduling module automatically manages concurrent accesses to the same device. The laboratory can be used in two different ways: the user can create a new project and write source code from scratch or load an existing project from a repository. Remote laboratory sessions are integrated in The Aulaweb portal course management system of the University of Genoa and it is based on the Moodle platform. Remote laboratory sessions are introduced by guidelines that explain lab activities.

In the paper [17] authors have presented the new web-learning system, which combines two educational resources, the virtual and remote laboratories (VRLs) and the synchronous collaborative learning practice. The main objective of the developed system is to offer a shared VRL that can be controlled in real-time by different members of a virtual class (students and teacher) and to be able to share the same experiments. The collaborative e-learning system that authors have been developed allows a group of students to share experiences at the same time they practice using VRLs. This system also permits teachers to track, supervise, and help students in their experimental exercises in a synchronous way. The VRLs are based in Java applets developed in Easy Java Simulations (EJS). During the teacher tutorial time, students connect to the teacher and ask questions through Skype. The shared VRL is composed of an applet for each class member. Authors are currently working on applying their collaborative synchronous system to remote network laboratories.

Some other authors deal with the pedagogical aspect of DSP learning [18], [19], [20] and [21].

One approach where remote experiments are treated as learning objects, which are stored in a repository, developed and presented in [18]. Advantages of virtual experiment regarding several pedagogical features, such as identification and profiling, discussion forums, testing, report preparation and delivery, user statistics and feedback, have been underlined in this paper.

The educational experience consists of the helping for technology students, who generally learn by Active Experimentation, develop, to some extent, the abilities of Abstract Conceptualization, through innovative teaching technique and enhance their interest in a multidisciplinary curriculum, described in the paper [19].

For the purpose of “visualization” of filtering concepts, LabVIEW filter palette has been used for the virtual experiment of band pass digital filter design and active band pass filter [20]. These virtual experiments also have been realized on hardware developing platform NI-ELVIS II+. Theoretical characteristics of active band pass filter validated by measurements on realized hardware model. Pedagogical issues concerning meeting different learning styles through integration of those virtual and hands-on laboratory experiments in DSP laboratory are elaborated in the [20].

The traditional approach of teaching engineering concepts that comes as the combination of classroom teaching and homework exercises lacks the student's intuition for applying same concepts to different new problems. The integration of virtual and hands-on laboratory experience in addition on theoretical DSP concepts creates the perfect match for improving student practical skills. On the basis of mixture of on-site and remote exercises and web-based teaching materials, blended delivery mode of advanced DSP course at Master study program in Electrical and Computer Engineering, is enabled.

We use on-site MATLAB/SIMULINK® and LabVIEW virtual interactive DSP experiments and hardware DSP laboratory experiments on the NI-ELVIS II + development platform as well as remote DSP experiments on the NI CompactRIO platform in our DSP lab for "visualization" of some course topics

in Advanced Digital Signal Processing as a part of our ongoing efforts in DSP laboratory development.

Individual differences in cognitive learning styles e.g. student's mode of thinking, perceiving, remembering, or problem solving are quite obvious when teaching science or engineering. This indicates that multiple approaches are needed to achieve the best for students. Using student survey we have discovered that we can meet different learning style of our engineering students through integration of on-site and remote DSP experiments.

2. Blended DSP course supported by On-site and Remote experiments

Course in Advanced Digital Signal Processing is the obligatory course of Master Study in Remote Control Curriculum and Master Study in Computer Engineering Curriculum at Technical Faculty Cacak, University of Kragujevac. The main course objectives are to gain:

- The knowledge of advanced signal processing techniques such as random signals filtering, spectral estimation and prediction and adaptive filtering, and to use it in the present-day control systems and engineering applications.
- The use a combination of theory and software and hardware implementations in solving practical signal processing problems.

After completion of this course, each student is expected to be able to:

- Describe and analyze discrete time stationary stochastic signals, in terms of their autocorrelation sequence and spectral density, and to determine how these properties are affected by linear filtering
- Know how to perform sampling and reconstruction and describe how these operations affect both deterministic and stochastic signals, in the time and frequency domain
- Estimate the spectral density of a signal, based on a limited number of noise samples, especially:
 - implement and use non-parametric methods for spectral estimation.

- implement and use parametric methods for spectral estimation.
 - estimate parameters in the models, using MMSE and least squares methods.
 - use the models with the estimated parameters in applications such as spectral estimation and prediction.
- Know how to perform adaptive filtering.
 - Use a combination of theory, hardware and software implementations to solve practical signal processing problems.
 - Think critically, ask questions, and apply problem-solving techniques.

Considering that some of our master students are from the cities dislocated from Technical Faculty place and some of them are employed, we use blended delivery mode for teaching and learning on this course. The course comprises theoretical lectures, placed on the Moodle LMS system, lab and computer sessions. Beside lectures, additional teaching materials, like different tutorials and virtual experiments hosted on the laboratory Moodle system and delivered through the web.

On-site lab exercises with appropriate computational examples and short theoretical test before the lab exercise are organized on the weekends for each of main tree topics of course: Spectral analysis of stochastic signals, optimal filtering and Adaptive filtering.

We use MATLAB software package and The National Instruments (NI) hardware with NI LabVIEW software in our DSP laboratory for creating virtual and hardware experiments.

MATLAB software package has become standardized and inevitable simulation tool for “visualization” of DSP theory. Many MATLAB based DSP “visual experiments” are constituent parts of lectures and practical exercises at the courses of system and signal theory and digital signal processing for a long time.

Like MathWorksInc., National Instruments also offers nowadays plenty of opportunities for incorporating NI hardware and NI LabVIEW software in a classroom and remote laboratory for teaching and learning DSP. Integration NI hardware

and LabVIEW software is almost seamless.

For the reason of achievement the better results and to meet different learning styles we provide our students to exercise on remote DSP experiments via the web in addition to on-site lab sessions.

We foster the class and web discussions via forum to enhance collaborative work during student’s work on on-site and remote laboratory exercises and solving their homework. In this way the simulation of real work engineering environment is done.

This approach of combining of on-site, virtual and remote experiments compensates the disadvantages of one type of experiments with the advantages of other one [15].

2.1 On-site DSP hardware experiments

Modeling and simulation in virtual laboratory environment based on MATLAB and LabVIEW software cannot completely prepare students of Electrical Engineering for work with hardware equipment because they will have to experiment a lot within their future engineering practice during the designing, testing and running of practical engineering applications. The aim of hardware laboratory experiments in education of engineers through “physical contact with hardware” means better understanding of acquired theoretical knowledge in order to apply it more successfully in future engineering practice. It is especially important for the courses with complex mathematical background such as Advanced Digital Signal Processing.

Regarding “physical contact with hardware” we integrated several hardware experiments into the realization of course in Advanced Digital Signal Processing.

One of the on-site hardware DSP experiments in our DSP laboratory, created in the aim of better understanding of theory of course topic in adaptive filtering, illustrates implementation of LMS (Least Mean Square) algorithm on NI cRIO 9074 FPGA hardware platform. NI 9205 as an input module and NI 9263 as an output module are also used as additional hardware components.

The used hardware platform is an advanced embedded control and data acquisition system

designed for applications that require high performance and reliability. NI CompactRIO is powered by National Instruments LabVIEW FPGA and LabVIEW Real-Time technologies, giving engineers the ability to design, program, and customize the CompactRIO embedded system with easy-to-use graphical programming tools. This chassis contains the Spartan-III FPGA chip with 2M gates that offers ultimate processing power and the ability to design custom hardware using LabVIEW FPGA software. This is an embedded real-time controller module featuring an industrial 400MHz Free scale MPC5200 real-time processor for deterministic and reliable real-time applications. The chassis containing the FPGA has 8 slots to connect external hardware modules, used for signal acquisition. The real-time controller contains a 10/100BaseT/TX Ethernet port to communicate with the PC or with other systems. The LabVIEW suite is used to implement the hardware architectures for signal processing. [22]

Another used hardware is a Ni 9205 input module. The NI 9205 is a C Series module, for use with NI CompactDAQ and CompactRIO chassis. The NI 9205 features 32 single-ended or 16 differential analog inputs, 16-bit resolution, and a maximum sampling rate of 250 kS/s [23].

The NI 9263 is a 4-channel, 100 kS/s simultaneously updating analog output module for any NI CompactDAQ or CompactRIO chassis [24].

Adaptive filtering is one of the inevitable topics in advanced DSP courses. LMS algorithms are a class of adaptive filter method used to mimic a desired filter by finding the filter coefficients that relate to producing the least mean squares of the error signal (difference between the desired and the actual signal). It is a stochastic gradient descent method in that the filter is only adapted based on the error at the current iteration [25].

The laboratory environment for hardware experiment concerning LMS adaptive algorithm “visualization” is shown in the Fig. 1.

The experiment regarding noise cancellation carried out in the NI LabVIEW FPGA programming environment by using adaptive LMS algorithm.

The hardware experiment described above carried out by using of sine wave input signals which was

compromised by noise. The input signals were set as follows: a sine wave with 0.4V amplitude and 30Hz frequency and the noise signal with 100Hz frequency. The input noisy signal in comparison with the smooth one is shown in the Fig. 2.



Figure 1. The laboratory environment for LMS adaptive algorithm hardware experiment

A system is said to be adaptive when it tries to adjust its parameters with the aim of meeting some well-defined goal or target that depends upon the state of the system and its surroundings. So the system adjusts itself so as to respond to some phenomenon that is taking place in its surroundings. In this case we can said that “surroundings” is noise (first graph in the Fig. 2) and when the process of adaption is done, smooth sine wave signal will be appear on the output of adaptive system (second graph in the Fig. 2).

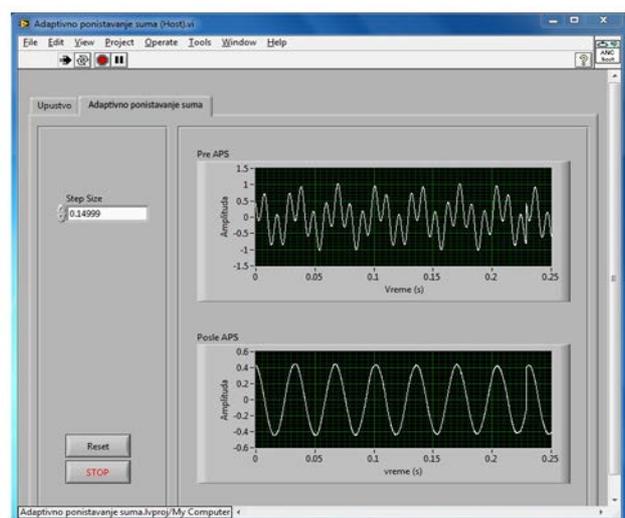


Figure 2. The input noisy signal in comparison with the smooth one 1) signal + noise 2) filtered signal

This is one of good examples for learning how adaptive LMS algorithm can be used in practice that is how the theoretical DSP concepts learned in the classroom are ultimately implemented in a real time embedded DSP system.

Similar implementation of the LMS adaptive algorithm on the NI cRIO-9104 FPGA chassis by using of 20 bit fixed-point arithmetic, have presented in the paper [26]. The design is evaluated in terms of SNR, filter length and FPGA resources. The tracking performance of the LMS derivatives in adaptive noise cancellation for a speech signal corrupted by white noise analyzed in the [27] by using the same NI cRIO-9012 module.

2.2 On-site MATLAB/SIMULINK® DSP experiments

MATLAB software package has become standardized and inevitable way of “visualization” of DSP theory for a long time. Many MATLAB based DSP “visual experiments” are constituent parts of lectures and practical exercises at the courses of system and signal theory and digital signal processing.

Ready-made MATLAB solutions known as “toolboxes”, provide large range of options in combination with Simulink. DSP System Toolbox and Simulink provide algorithms and tools for the design and simulation of digital signal processing. These MATLAB capabilities is of great importance for education of future engineers, because all theoretical concepts can be “seen” by using of MATLAB simulation that faithfully illustrates the processes in a practical environment.

We can design digital filters by MATLAB using either the Digital Filter Design block or the Filter Realization Wizard. These blocks are capable of calculating filter coefficients for various filter structures. In this section, design of LMS adaptive algorithm by using of the Digital Filter Design block is described. We used the conversion of white noise to low frequency noise to simulate white noise effect.

In order to learn how adaptive LMS algorithm can be used in practice, we have simulated a practical application [28]:

Suppose a pilot is speaking into a microphone within the cockpit of an airplane.

The noise of the wind passing over the fuselage is also reaching the microphone. A sensor is measuring the noise of the wind on the outside of the plane. We want to estimate the wind noise inside the cockpit and subtract it from the input to the microphone so that only the pilot's voice is transmitted. Fuselage converts white noise, derived from wind, into low-frequency noise. This noise contains certain frequencies that have to be filtered. Low-frequency noise is transmitted to a microphone with a pilot's voice. The system, which converts white noise to low-frequency noise, have been created in Simulink by using Digital Filter Design block.

Adaptive filters track the dynamic nature of a system and allow us to eliminate time-varying noise signal. The DSP System Toolbox libraries contain blocks that implement least-mean-square (LMS), Block LMS, Fast Block LMS, and recursive least squares (RLS) adaptive filter algorithms [28]. We have design an LMS adaptive filter to remove the low frequency noise from the signal.

In the aircraft scenario, the adaptive filter removes the low frequency noise heard inside the cockpit, so the pilot's voice is the only input to the microphone. The Simulink model for removing noise from the microphone signal is shown in the Fig. 3.

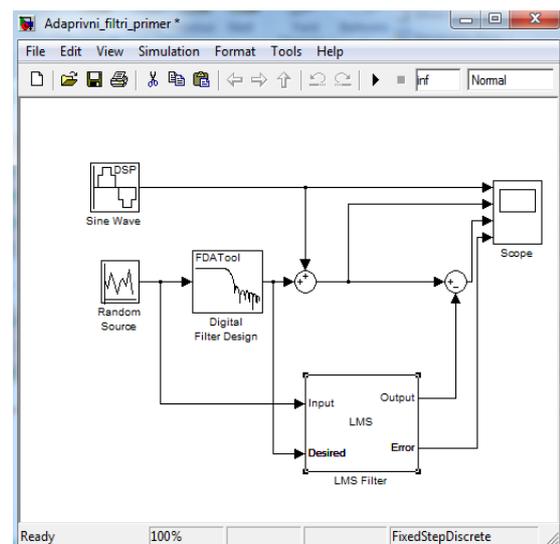


Figure 3. The model of adaptive noise cancellation

The results of the adaptive noise cancellation are shown in the Fig. 4.

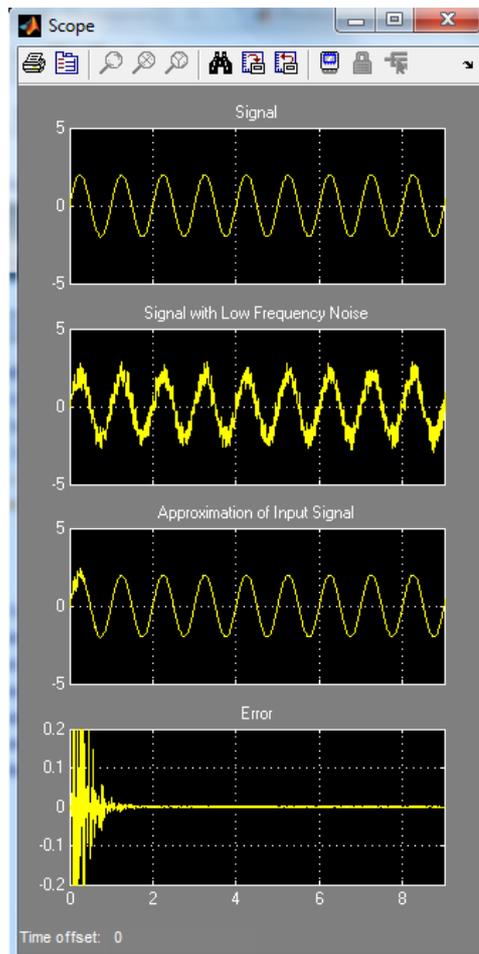


Figure 4. The results of the adaptive noise cancellation

First graph in Fig 4 represents the signal which simulates the voice of the pilot. This signal has to be translated through a microphone to the certain receiver. Second graph indicates that the first signal is compromised by low frequency noise. This signal has to be filtered by adaptive LMS algorithm. The result of process of adaptive noise cancellation is shown on third graph. This signal is the microphone signal from which the noise has removed during adaptation process. The fourth graph represents the signal of adaptation error.

It can be seen that the adaptation error decays to zero quickly.

2.3 Remote DSP Experiments

Web-based remote experimentation enables remote users to develop skills, which deal with real systems and instrumentation with the added advantage of providing broader access to expensive specialized equipment at any time and from any location [1]. When students interact remotely with the laboratory

plants they have the opportunity to verify what happens when they modify and manipulate the experiment. Besides, the student can run the same experiment, more than once.

The combined use of FPGA/PC connected test hardware and appropriate software may open a way to develop a remote multi-user time-sharing system for hardware experiments, where students at remote terminals can perform actual experiments using real hardware equipments and tools remotely from home or students residence.

The remote laboratory, accessible from anywhere through the Internet connection, has been built according to the general methodology to control instruments through Internet [1]. Basic structure of the laboratory is shown in Fig. 5

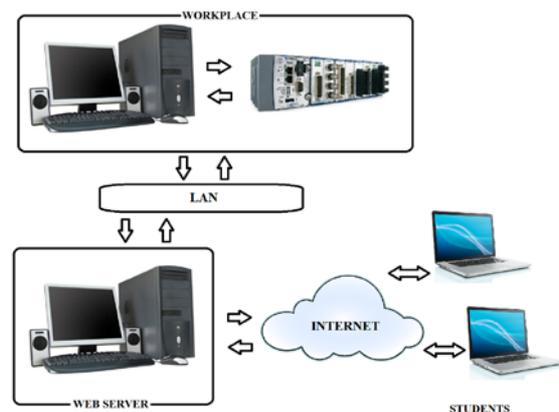


Figure 5. Basic structure of remote laboratory

The workspace in the Fig. 5 in case of our DSP laboratory supports standard iterative FPGA design and testing flow and provides hardware platform for the experiment of noise cancellation that carried out in the National Instrument LabVIEW FPGA programming environment. This experiment (described in 2.1) we realized previously as on-site hardware experiment (Fig. 1).

Lab View has its internal web-server, supporting web-publishing of the created models and algorithms. This option allows us to remotely control cRIO platform and LMS adaptive algorithm implemented on the platform.

In order to allow students to run the algorithm remotely, we configured the network in the following way: the computer running Labview and the cRIO platform are connected to the same LAN network, using Wi-Fi router, which is further, connected to the

Internet and got a public IP address. The Labview's web-server is listening on port 8000, and this port is forwarded on the router, thus the remote user might get to the PC in the LAN and use the web-page generated.

By using Web publishing tool option we assign the URL address for our application. Actually, this is the router's public IP, and using this address the remote user access the hardware or software which is connected to the PC running Labview. The result of remote hardware experiment on the remote user side is shown in the Fig. 6. It is evident that this result is the same as the one carried out as on-site hardware experiment (described in 2.1).

There is a drawback to this remote-experiment scenario: only one user may access to the remote experiment at the same time. Therefore, the usage should be well planned and scheduled.

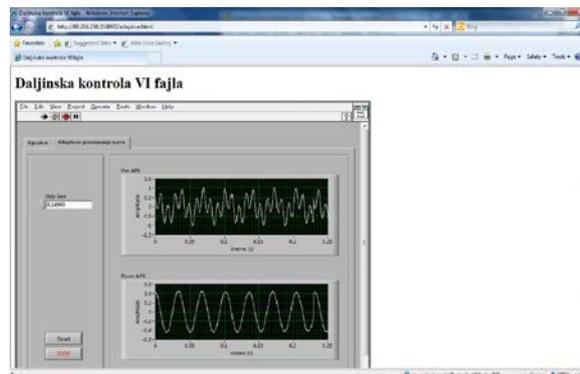


Figure 6. The result of remote hardware experiment on the remote user side

In better understanding of theory concepts in Advanced Digital Signal Processing the most helpful are: (rate with numbers from 1-4, 1 not helpful at all, 2 of very little help, 3- helpful, 4- very helpful)	1. Matlab simulations			
	2. Simulink simulations			
	3. LabView simulations			
	4. Hardware experiments			
For efficient gaining of skills and practical knowledge in Advanced Digital Signal Processing the most helpful are: (rate with numbers from 1-4, 1 not helpful at all, 2 of very little help, 3- helpful, 4- very helpful)	5. Matlab simulations			
	6. Simulink simulations			
	7. LabView simulations			
	8. Hardware experiments			
The most useful scenario, considering place and methods (check one experiment type for every item)				
	Matlab experiment	Simulink experiment	Labview experiment	Hardware experiment
9. In the lab it is most useful to learn individually with				
10. At home, doing remote experiment individually using				
11. In lab, with teacher's assistance				
12. At home, doing remote experiment with teacher's online help				
13. In lab, working in group				

Table 1. The questionnaire items

3. Student survey

In order to investigate what is the preferred form of lab exercises among our engineering students, an online survey was constructed. It consisted out of thirteen items, presented in a concise form, using Moodle's Questionnaire module. The group of 22 students was involved in the research. Items used are given in Table 1.

A four-item Likert scale was used for first eight items. For items 9-13 every choice was assigned a number from 1 (Matlab) to 4 (Hardware experiment).

Survey results shown that for theory concepts students prefer LabView, since more than 90% rated this lab exercise as very helpful or helpful. MatLab and Simulink got similar results, while hardware experiments shown as helpfull in about 70% of cases.

For practical knowledge students also mostly preferred LabView, again over 90% „helpfull“ rates.

In third items category, for item 9, hardware experiment was most preferred with about 50% votes. Item 10 showed that about 50% of students prefer Matlab, a bit less was with item 11. At item 12, equal preference was shown for Matlab and LabView, about 40% for each. At item 13 almost 50% of students preferred hardware experiment, followed by Matlab (25%), LabView and SimuLink.

4. Conclusion

It is obvious that is significant number of authors deal with remote and virtual lab exercises in recent years. That is from the reasons of the importance and potential of remote and virtual labs for the enhancement of the learning process in engineering education in the classroom or in an e-learning and blended learning environment. This is should be considered in context of overcoming the gap between understanding mathematical formalisms in engineering courses and practical application deployment.

We have created blended learning environment by integrating virtual and hands-on laboratory practices together with on theoretical DSP concepts to enhance the teaching process for engineering students at the master study course in Advanced Digital Signal Processing at Technical Faculty Cacak, University of Kragujevac.

The extensive survey was conducted to test what the preferred form of lab exercises by combining the questionnaire items on usability on understanding of theory concepts and practical skills and knowledge on course in Advanced Digital Signal Processing. As expected, the obtained results showed that for the most of our students preferred hardware and LabVIEW experiments which obviously indicated that these two kinds of experiments are the most suitable for engineering students as them distinguished by practical learning and useful activities for them are skills practicing [21].

We are going develop our DSP laboratory towards the usage of the remote experiments in an e-learning scenario based on common learning platforms such as Moodle. The authentication of the remote users and the scheduling of the remote experiments have to be solved in such a way that experiments can be controlled in real-time by students and teacher in the virtual class allowing them to share the same experiments like in a traditional classroom. Teachers and students will be enabled to share practical experiences in an collaborative e-learning synchronous environment.

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