Ultrasound Medical Diagnostics Laboratory for Remote Learning in EVICAB* Campus

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***Abstract*- The aim of this paper is to present the development of remote learning laboratory for ultrasound medical diagnostics. We demonstrate the implementation of such laboratory using virtual instrument that is built by using standard PC, ultrasonic transducer with tissue like phantom, digitizer (Picoscope ADC 212/100, Picotech Ltd.), function generator (Hameg HM8131-2, Hameg Instruments GmbH) and popular software package LabView (National Instruments Inc.). By controlling the virtual instrument it is possible to excite and receive ultrasound waves in pulse echo mode then process the received echographic signal and get the characteristics of tissue like phantom. The tissue like phantom is characterized with thickness and density also with the speed of waves propagation and attenuation coefficient. The students are motivated by the assignment of the clear task - to identify the material from which the phantom is made. The implemented virtual instrument is based on NI Remote panel technology. This technology allows to access the virtual instrument remotely using internet browse. The lab preparation materials: goal, theory, quizzes are available from e-learning platform Moodle. We expect the students will improve their knowledge of ultrasound tissue characterization using our remote hands-on labwork.**

Keywords: ultrasound, medical diagnostics, remote learning laboratory, courseware

I. Introduction

John Dewey (1859-1952) was an American philosopher and educator whose writings and teachings have had profound influences on education in the United States and around the world [1]. Dewey's philosophy of education called pragmatism and teaching methods focused on learning-by-doing (experiential learning) rather than rote learning and dogmatic instruction, which were common practices in his days. For Dewey, it was vitally important that education should not be the teaching of mere dead fact, but that the skills and knowledge which students learned be integrated fully into their lives as persons, citizens and human beings.

Internet helps to make feasible the Devey's ideas as new kind of laboratories- remote laboratories appear with real interactive experiments by using internet connected laboratory equipment: measurement instruments and devices under investigation. Emerging technologies of electronic learning and teaching platforms are spreading in the higher education system. Many examples of remote labs for different subjects do exist already: in electronics [2] and microelectronics [3], systems and control [4] and photonics [5].

However, the implementation of remote lab for such specific subject as Ultrasound medical diagnostics is not widely published yet [6, 7, 8]. We can refer to grant awarded implementation by H. Ewald et.al [9] who published their experience in remote ultrasound experiments. The specifics of ultrasound technology and the importance of knowledge in ultrasound diagnostics motivated us to create the advanced courseware for graduates in Biomedical Engineering program. In this paper, we present the development and implementation success of Ultrasound medical diagnostics laboratory for remote learning.

II. Motivation and Methodology

The common established clinical practice of medical diagnostics, sonography, aims to non invasively characterize structure of internal human organs. We can illustrate usage of ultrasound diagnostic systems with a number of these diagnostics cases at university hospital in Lithuania: near 91 thousand procedures per 2004 year [10]. These volumes argue themselves how it is important to maintain the adequate competence of medicine doctors and biomedical engineers in principles of ultrasound medical diagnostics.

The most frequent form of sonographic systems is images of internal anatomical structure i.e. qualitative data. Evaluation or interpretation of those images is the specific and complicated expertise field of radiology-sonography professionals. The image processing software tools are applied to interpretation of sonography images often without waves and tissue interaction taken into account. However, the survey of research publications shows the increasing specialization of sonographic systems for diagnostics of particular organs and increasing demand for quantitative data about the tissues under investigation. Description of biological tissue non-invasively in quantitative parameters is called tissue characterization. We can provide a whole row of modern attempts of ultrasonic

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tissue characterization in scientific research papers: diagnostics of body common tumors [11]; diagnostics of breast tumors [12]; characterization of myocardium [13]; evaluation of vascular condition [14]; evaluation of elasticity of eye lens [15], determination of liver suitability for transplantation [16], characterization of bones [17] and cartilage [18], tissue attenuation imaging [19]; or parametric imaging with sonographic system [20].

Responding to such demand we are aiming to teach the students the principal side of sonographic technology in-vitro, which is building component of the pulse echographic method to characterize the biological tissue. In-vitro experiments gave the basic data about ultrasound wave propagation parameters, such as: sound speed, sound reflection from and transmission trough tissue boundary interfaces, sound waves attenuation.

A. *Learning content of laboratory experiment.*

The main goals of experiments are:

1. Demonstration of ultrasound wave's phenomenon and to structure possibilities of theoretical calculation and hands-on experiments.

2. To perform experiments with ultrasound waves, to learn waves application possibilities in ultrasound diagnostics.

3. Provide knowledge in operating computerized experiments, when pulse echo waves are applied.

Laboratory experiment includes four main stages: self-sustained preparation and preliminary tests before experiments; hands-on experiment, results documentation and report preparation, interpretation of results, conclusions and after labs testing quizzes.

1. Preparatory stage. Students should study laboratory description texts before starting the experimenting. Then he/she calculates relevant parameters, familiarizes with experiment hardware and software. During preparatory calculations student starts drafting the report, quality of which is improved in the following stages.

2. Practical stage. Students accomplish hands-on experiments using remote panel of the virtual instrument according to description in Moodle courseware. The obtained results are saved in the graphical and numerical format into draft of the report.

3. Documentation stage. Students taking the course are advised to use electronic form of experiment report to make the preparation more easy and purposeful. We think that such electronic preparation of the report preserves students' energy and time and facilitate students for analyzing, thinking about and perceiving the findings of the experiments. The report draft form, as a guide trough experiments, is available for downloading. The students begin to fill in the form during self-sustained preparation for experiments. During experiments students are collecting (inserting) graphical and numerical results of the experiments into the report. After completing experiments students process the results and further improve the quality of the reports. Finally, students formulate conclusions taking into account experimental and calculated results and, by comparing the experimental results with calculated ones, they have to answer labs quiz.

4. Formative assessment stage. Students should take the after-lab quiz, which is prepared in order to test how well the students have perceived the findings of experiments and have learned the subject. The after lab quiz is available online in Moodle learning platform.

III. SOFTWARE AND HARDWARE

A. *Courseware platform - Moodle*

We describe here so-called courseware or the didactic materials for self-preparing and performing the remote laboratory experiments including texts, equations, test quizzes, the software and hardware installed on remote laboratory. The materials contain the methodology description and derivation of equation how to characterize material from features of echo pulses. The equation contains echogram and pulses data given in Fig.3 b. The calculations of parameters are programmed in the virtual instrument, but students after reading the method development chapter should get an idea of these "hidden" calculations. Experimentally estimated parameters help students to identify what the material was in the phantom. Identification of material is the interpretation task for students. They should compare obtained parameters with the parameters from the materials catalog and identify investigated material.

The learning materials are available in EVICAB project's e-Learning platform Moodle. This web site serves students and is good alternative of textbook. Implemented quizzes facilitates assess of knowledge improvement after experiments.

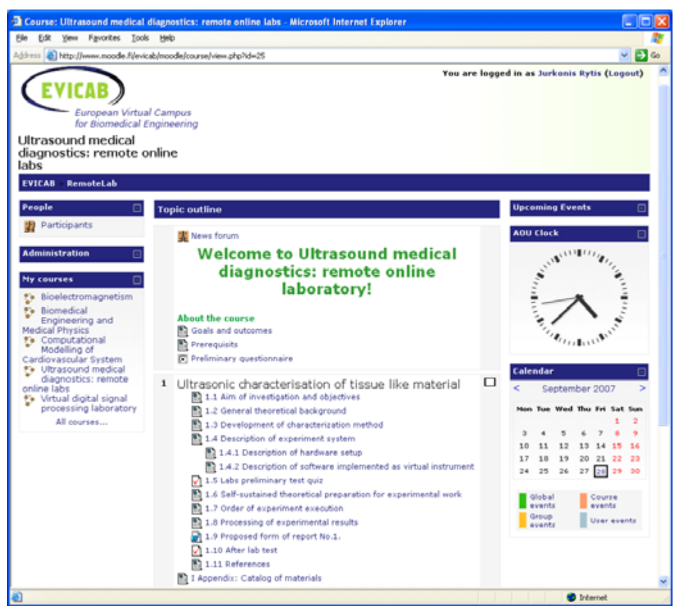

Figure 1. The screenshoot of Ultrasound Medical Diagnostics e-Learning platform implemented in Moodle. It is possible to visit using this link: http://www.moodle.fi/evicab/moodle after registration.

B. *Virtual instrument software*

Virtual instrument is a program that implements functions of the measurement instrument with the aid of computer and some peripherals: signal digitizer, generator etc. Virtual instrumentation concept was introduced by National Instruments Inc. (NI) 20 years ago. NI's software package LabView is widely used for development of the software for virtual instruments [21]. We have also used LabView for development of virtual instruments for on site lab work at laboratory [22]. Digital signal processing is performed using software tools in virtual instrument. The raw echogram was prefiltered with bandbass filter to sub-press noise. Amplitude data in echogram is evaluated automatically by virtual instrument, but the delay data of pulses is evaluated by manual scrolling of virtual control. The virtual instrument calculates the following parameters of tissue like material: thickness d, density ρ, and ultrasound waves speed c. The fast Fourier transform computed the amplitude spectra of echo pulses, then log spectra differences were approximated linearly using least square method. From slope of approximating line the attenuation coefficient β is estimated. Methodology of material characterization is so called substitution method and is adopted from [23].

The developed remote panel of virtual instrument is also able to set-up hardware remotely, to process the acquired data and to present the numerical and graphical results on the remote panel over internet connection (see Fig.2.).

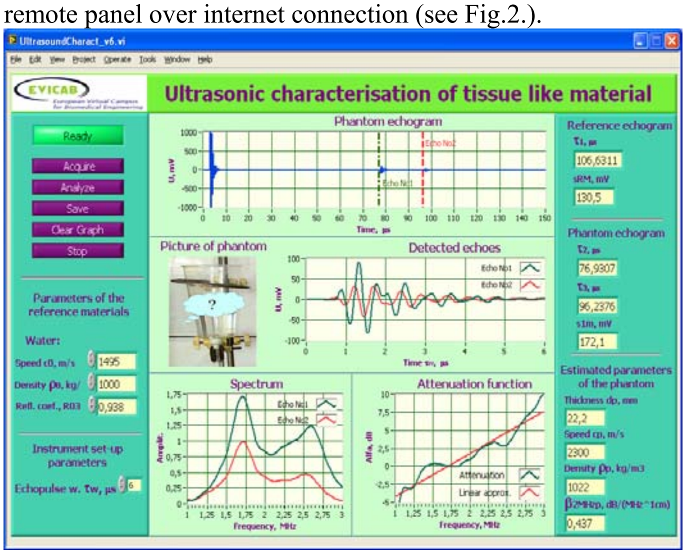

Figure 2. The remote panel of the virtual instrument.

We faced the problem when shifting from on site labs to remote labs: how to organize experiments so that all students could have opportunity to perform experiments remotely without disturbing each other. The partial solution to this problem could be the time scheduling or booking system [24]. The phantom samples could be interchanged by the teacher according to known schedule.

C. *Hardware*

The experimental system is based on high speed (100MHz), high resolution (12bits) digitizer Picoscope ADC 212/100 (Pico Technology Ltd., Cambridgeshire, UK), function generator Hameg HM8131-2 (Hameg Instruments GmbH, Mainhausen, Germany), ultrasound transducer (central frequency 2,25 MHz, aperture 13 mm in diameter), matching circuit, and custom-built software in LabView (Fig. 3 a). The digitizer is used for sampling and acquisition of ultrasound signals. Digitizer and computer are connected via LPT (parallel) port. The function generator is used for excitation of the transducer and for sending the pulses of ultrasound waves into phantom. Ultrasound transducer is excited with pulse, which duration is controlled from virtual instrument via IEEE-488 (GPIB) interface.

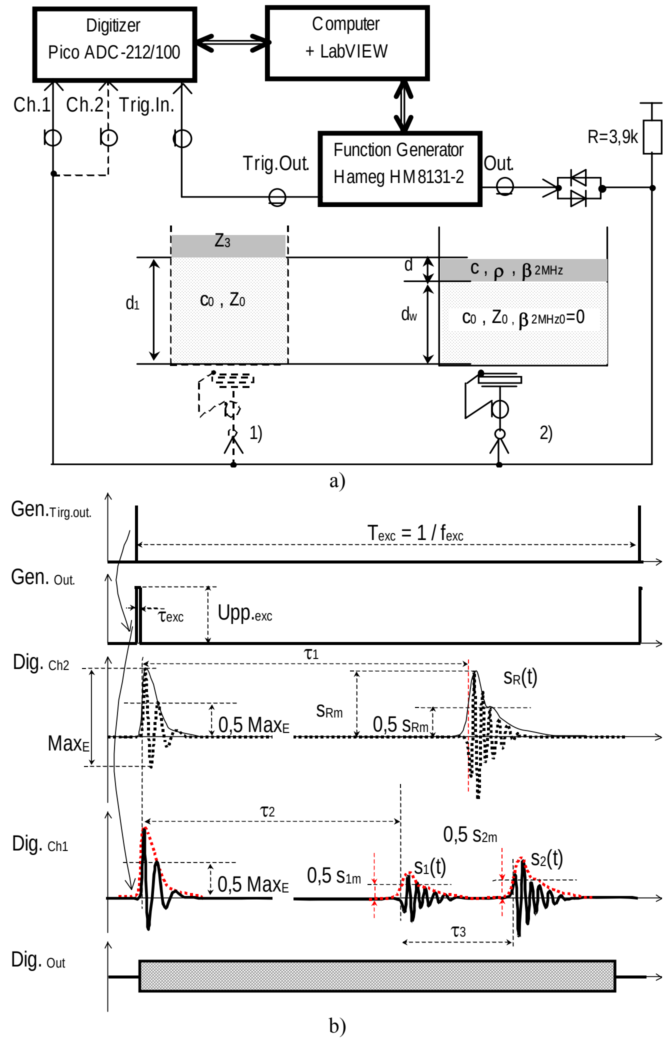

Figure 3. The structure of experimental system (a) and time diagrams illustrating the tissue characterization method (b).

IV. Discussion

We would like to discuss our experience in implementing virtual experiments system for remote learning of ultrasound medical diagnostics principles in a few aspects. The first aspect we want to discuss is the amount of interactivity needed to perform the experiment. There is danger of too much automatic experiment when students will lack the interaction. On the other hand, if students are left with manual processing of the acquired data, the path to the results could be too complicated for them and nobody will succeed. Thus the goals, to show the power of ultrasonic tissue characterization, could be not reached. The practical clinical applications of experience gained in the experiments could be tissue characterization at tissue banks for transplantation, or at pathology and anatomy departments where characterization results are verified. The third aspect of implementation is collaborative work of experts from different fields. The co-authors have put together their specific knowledge during implementation of labs platform. One co-author was ideological leader of labs methodology, the other was expert in ultrasound. In this way, we found feasible the adoption of newest methods and solutions of ultrasound diagnostics [25] for learning. The third important contribution was the knowledge of LabVIEW virtual instruments and of learning platform Moodle.

Analog and digital electronics equipment, ultrasound transducers and digital signal processing software tools from LabVIEW are used in remote labs. The hardware is as standard as possible, while the required specific signal processing methods are implemented in software tools and adopted for labs goals and objectives. Such composition of experiments equipment cut the price and eliminated depreciation of specialized and expensive hardware.

The digital domain signal processing algorithms are rapidly developing and have the increasing importance in ultrasound diagnostics. Virtual implementation of instruments will enable us easily to modernize the lab by the simple change of software algorithms. Therefore students will get the most up-to-date system to work with. This is important aspect of virtual experiments systems development taking into account the constrains of capital and time resources.

V. Conclusions

We presented the approach of the remotely controlled laboratory experiments for the course of Ultrasound medical diagnostics in Biomedical Engineering master program. An approach was implemented and tested in one example of lab work "Ultrasound characterization of tissue like material". It should be noted that implementation of specific subject (e.g. Ultrasound medical diagnostics) on remotely controlled laboratory system is demanding work of collaborating experts. We think that such courseware implementations should be most efficient if at least one expert of ultrasound diagnostics and one expert of e-Learning platforms (e.g. Moodle and LabVIEW) would collaborate. We found it is feasible to implement a few more remote experiments using the same equipment for: sonographic M scanning and Doppler device principles learning in the future.

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