

Development of Virtual and Remote Lab Experimentation System for Electronics Engineering

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Introduction

Outstanding philosopher and educator John Dewey (1859-1952) had promoted new teaching methods focused on learning-by-doing (experiential learning) rather than rote learning and dogmatic instruction [1]. His concept of education called pragmatism strongly influenced the education systems in all levels – from basic to advanced.

Modern information, communication and electronic technologies created new implementation possibilities of Dewey's ideas. A new kind of laboratories - remote laboratories appeared offering real interactive experiments by the use of internet connected real laboratory equipment - measurement instruments and objects under investigation. Many examples of remote labs for different subjects do already exist: in electronics [2,3], microelectronics, systems and control as well as in photonics.

However, the complex implementation and testing of flexible experimentation system suitable from introductory level learning and basic experiments till the advanced level and scientific research - remains a significant problem.

Good pilot developments for the specific subject - Ultrasound medical diagnostics - were published in papers [4,5,6]. Promising results and student satisfaction motivated us to create the more advanced and more versatile courseware for graduates in Biomedical Engineering and electronics programs and experimentation tools for doctoral students.

Present paper deals with development of remote experimentation system which allows to access and control by internet real hardware instruments, real physical object, perform experiments, calculation, generate reports and get an evaluation. Main features of the system developed is modularity (system contains configurable software and hardware modules), flexible configurability (modules could be composed in pre-defined architecture) and interactivity (students are dealing with real world objects and devices). Examples of several implemented configurations for pulse parameters registration using emulated oscilloscope, hands-on ultrasound characterization of tissue like material and advanced

Doppler experimentation system for heamodynamics research were presented and working experience discussed.

Structure of remote experimentation system

Figure 1 shows general structure of the virtual instruments based experimentation system for education and research. The system can be controled on site or remotely. The user interfaces are the same in both cases. The system consists of LabView based software and hardware modules (computer, signal digitizer and generator) also real objects under investigation and transducers (see Fig. 1).

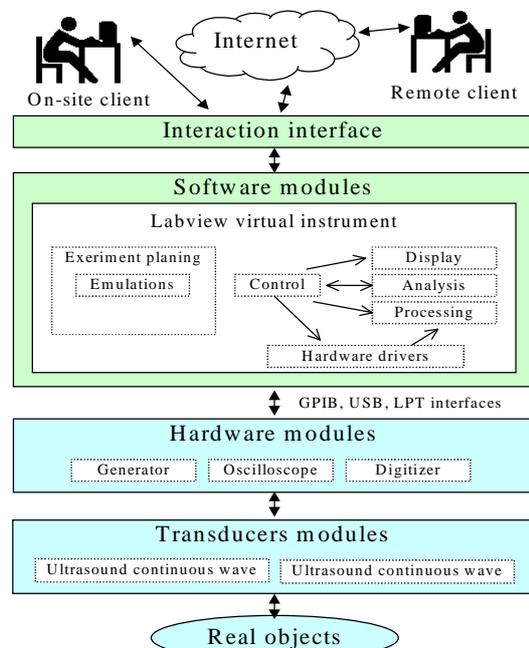


Fig. 1. Outline of the client – server internet connected remote experimentation system

In education scenario, students start experimentation by using simulated objects and emulated (simulated) measurement instruments. Then, when concepts are already mastered, the students are prepared for specific

experiments with real equipment, transducers and objects. In research scenario, the system can be used for monitoring of long running experiment, gathering the data from different distributed sensors and transducers.

Basics modules and exercises example for bachelor students

Software of simulated experiments can in some sense replace the teacher and become „e-teacher“. According to the model of learning and teaching proposed by Mayes and Fowler [7] the learning with technology can involve a cycle of conceptualization, construction and dialogue.

Figure 2 shows an example of such software. By using this labwork the student is able to develop the skills required in efficient control of oscilloscope in order to measure different parameters of pulse signals. At the conceptualization stage the student is introduced with concepts of 11 different parameters which describe the pulse signal waveform. This information is available for the student from “Info” tab in the user interface.

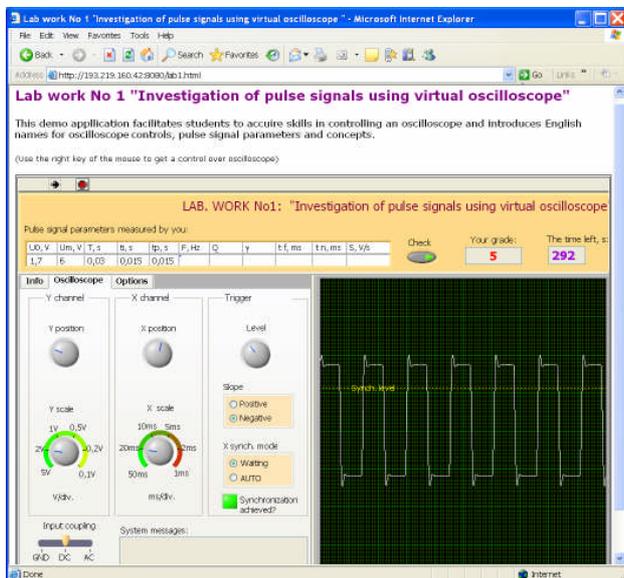


Fig. 2. The WEB based lab work which integrates three functional blocks: signal generator, oscilloscope and automatic “assessment”

At the construction stage, the student applies the developed signal parameterization and oscilloscope control concepts in real task– during the limited time, e.g. 10 min, he has to measure parameters of the pulse signal and write numerical values of estimated parameters in the table (upper part of Fig. 2). Student is assigned to estimate the following pulse parameters: DC offset, amplitude, pulse period, pulse duration, pulse repetition frequency, duration of rising and falling fronts, duty cycle and others. The pulse signal is generated internally in the program with the randomly selected parameters, thus it is impossible to memorize the signals. The student, in order to accomplish his task, uses virtual oscilloscope with all the relevant and working knobs and switches.

The dialogue stage happens at the same time as the secondary stage i.e. the student gets the feedback online in the form of the grade. If the grade increases by “1”, this means: the error of the just “measured” parameter is less than 10% and it is accepted as “right” answer. This stage

serves also as an automatic student assessment. The system stops and remembers the grade after the time is elapsed.

Specialized system for real life experiments

In spite of usefulness of simulated experiments, it is noticed that real experiments are more attractive to students than simulations. In order to be even more attractive they have to be built on latest technology and include some explicit and clearly stated challenge.

Internet made feasible new kind of laboratories - remote laboratories with real interactive experiments by using internet connected laboratory equipment: measurement devices, transducers and objects under investigation. In order to test such kind of system, we developed and implemented remote lab work “Ultrasonic characterization of tissue like material” which can be accessed within “Laboratory of Ultrasound medical diagnostics” [5]. The approach with details was published in [4,6].

The challenge presented to the student is: “based on remote measurements and analysis identify the material from which the phantom is made”. Laboratory experiment includes four main stages: self-sustained preparation and preliminary test before experiments; hands-on experiment, results documentation and report preparation, interpretation of results, and conclusions. At first student uses e-learning materials available to get acquainted with the methodology description and derivation of equation how to characterize material from features of echo pulses. The equations include data derived from echogram (see Fig. 3 b). The calculation of relevant parameters is programmed in the virtual instrument

The technology behind the remote lab includes hardware and software. 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) and matching circuit. All the hardware can be controlled by the student remotely using the virtual instrument built with Labview (see Fig. 3 a).

The first aspect which needs attention when planning such experiments is the amount of interactivity needed to perform the experiment. There is danger of too much automatic experiment. If this happens, the 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 can be too complicated and nobody will succeed. Thus the goal- to show the power of ultrasonic tissue characterization method- could be not reached.

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 constraints of financial and time resources.

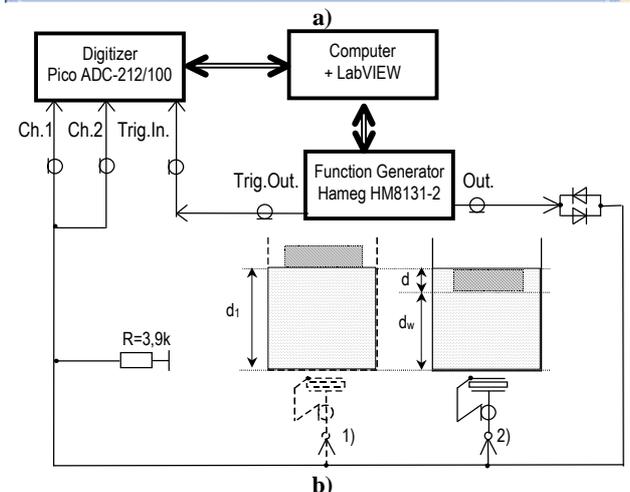
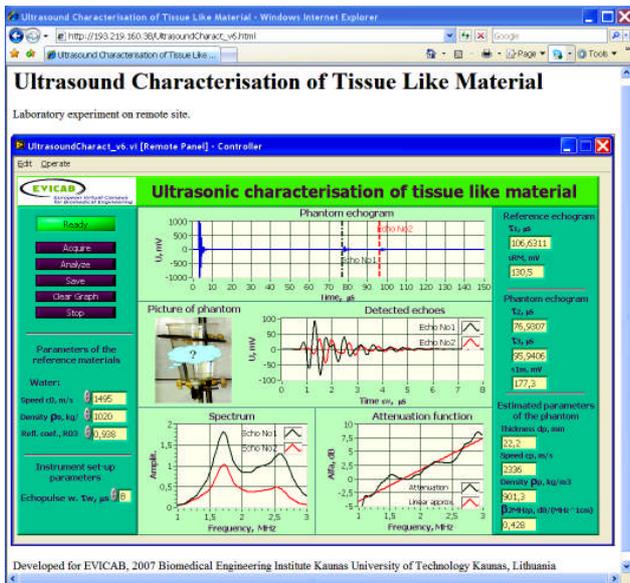


Fig. 3. Remote experimentation system: a - screenshot of remote client user interface, b – structure of hardware modules and real object

Advanced system for scientific experiments

The scientific, research oriented virtual instruments based experimentation system can integrate advanced methods of experiment planning and signal processing. We developed one example of such system - “Virtual instrument based system for investigation of hemodynamics parameters”. The system is based on the analog directional ultrasound continuous wave Doppler device (Model 806-C, Parks Electronics Inc.). The analog output signals from Doppler device are sampled by the computer sound card then, in the digital domain, advanced time-frequency transformation algorithms are applied and estimated parameters visualized (see Fig. 4 a).

Signal processing algorithm is performed in software of the virtual instrument (computer program). The algorithm includes stages of digital filtering, transformation of the signal into joint time – frequency domain by short time Fourier transform, parametrisation of the signal in the time – frequency domain in order to extract parameters related to blood velocity and flow turbulence. Short time Fourier transform is implemented by dividing the signal into short segments (10ms) and the Fourier transforming each segment:

$$STFT(t, f) = \int_{-\infty}^{+\infty} x(\tau)w(t - \tau)e^{-j2\pi f\tau} d\tau, \quad (1)$$

here $x(\tau)$ is the signal within the time window $w(t - \tau)$, variable τ pushes time window over the signal, while family of complex exponents $e^{-j2\pi f\tau}$ with frequency variable f are used for calculation of the local spectrum.

The Doppler shift frequency, which is proportional to blood velocity $v(t)$, is estimated as *time moment*:

$$f_d(t) = \frac{1}{E_x} \int_{-\infty}^{+\infty} f |STFT(t, f)|^2 df, \quad (2)$$

here E_x – signal energy.

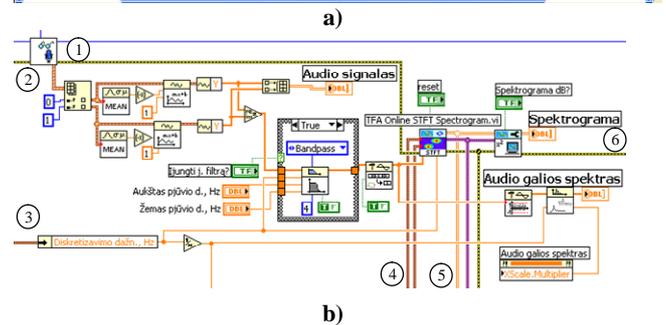
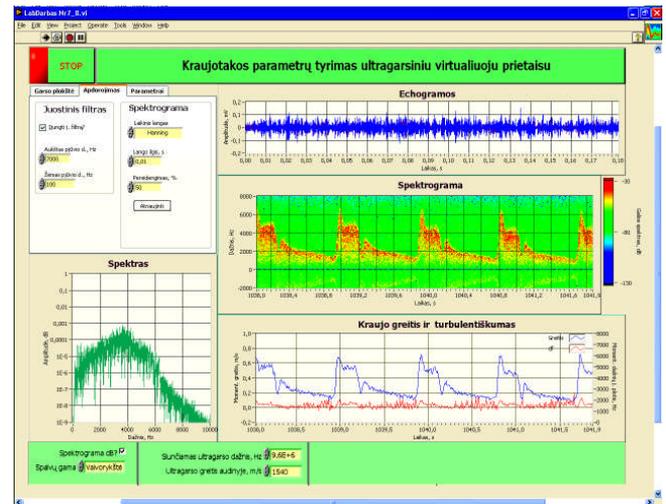


Fig. 4. Advanced ultrasound Doppler signal processing system: (a) - screenshot of user interface, (b) - fragment of the algorithm diagram of the virtual instrument (1 and 6 - error messages, 2 – audio signal read from sound card, 3 – audio signal sampling frequency, 4 – setup parameters for time- frequency transformation, 5 – data output after time- frequency transformation)

Doppler signal bandwidths is moderate if blood flow is laminar. However, if the blood flow is not laminar or even turbulent, the Doppler signal spectrum is wide. The cause for the blood turbulence can be constriction of blood vessels or aneurysms. Thus the increased bandwidths of the signal can be used as the diagnostic parameter of the vessels pathologies. The instantaneous bandwidths of the signal can be defined as the *second order time moment* of the time – frequency representation of the signal:

$$B_d(t) = \frac{4\pi}{E_x} \int_{-\infty}^{+\infty} (f - f_d(t))^2 |STFT(t, f)|^2 df \quad (3)$$

Fig. 4a shows the results of the real experiment in estimation of blood flow parameters in *arterija carotis*.

The virtual instrument performs all the calculations in real time and shows the results on large screen of the computer monitor. Details of advanced system is published in [4].

Conclusions

The approach of virtual instruments interfacing with measuring devices is feasible for implementation of learning-by-doing principles in electronics engineering studies.

We expect the students will improve their knowledge of development of modern systems using our hands-on experimentation systems, which are module based, flexible and expandable.

The approach presented also is suitable for sharing experimentation facilities among laboratories and institutions.

Acknowledgment

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The aim is to present the implementation approach of on-site and remote experimenting systems for several usage scenarios: basic mastering of concepts in electronics education (simulation experiments), specialised experiments or real life solutions in, for example, biomedical engineering and scientific research. All the experimenting systems are built as virtual instruments i.e. they integrate standard computer, specialized software developed in LabView and additional periphery devices: digitizer (Picoscope ADC 212/100, Picotech Ltd.), function generator (Hameg HM8131-2, Hameg Instruments GmbH), analog directional Doppler device (806-C, Parks Electronics Inc.), ultrasound transducers, and real objects under investigation. The students will improve their knowledge of development of modern systems using our problem oriented experimenting systems, which are modular, flexible and expandable. Ill. 4, bibl. 7 (in English; summaries in English, Russian and Lithuanian).

B. Марозас, Р. Юрконис, А. Лукошьявичус. Создание виртуальной и дистанционной системы лабораторных экспериментов для инженерии электроники // *Электроника и электротехника*. – Каунас: Технология, 2008. – № 7(87). – С. 41–44.

Цель состоит в том, чтобы представить подход выполнения локальных и отдаленных систем экспериментирования для нескольких сценариев использования: обучение основных понятий и приемов электроники (эксперименты моделирования), специализированных экспериментов или решений реальной жизни, например, в биомедицинских разработках и научных исследованиях. Все системы экспериментирования построены как виртуальные инструменты, они объединяют компьютер, специализированное программное обеспечение, выполненное на пакете LabView, и дополнительные устройства периферии: цифровой преобразователь (Picoscope ADC 212/100, Picotech Ltd.), генератор функции (Hameg HM8131-2, Hameg Instruments GmbH), аналоговое ультразвуковое устройство Doppler (806-C, Parks Electronics Inc) преобразователи ультразвука и реальные объекты исследования. Показано, что студенты улучшают знания о построении современных систем, используя гибкие, модульные системы экспериментирования. Ил. 4, библи. 7. (на английском языке; рефераты на английском, русском и литовском яз.).

V. Marozas, R. Jurkonis, A. Lukoševičius. Virtualios ir nuotolinės laboratorinių eksperimentų sistemos sukūrimas elektronikos inžinerijai // *Elektronika ir elektrotechnika*. – Kaunas: Technologija, 2008. – Nr. 7(87). – P. 41–44.

Pateikiama keletas lokalių ir nutolusių eksperimentavimo sistemų keletui vartojimo scenarijų: elektronikos mokslų baziniams gebėjimams ugdyti (imitavimo eksperimentai), specializuotiems ir realiems eksperimentams atlikti, pavyzdžiui, biomedicininėje inžinerijoje ir moksliniuose tyrimuose. Visos eksperimentavimo sistemos yra įgyvendintos kaip virtualūs instrumentai, t. y. jungia standartinį kompiuterį su specializuota LabView paketu sukurta programine įranga ir papildomais periferiniais prietaisais: skaitmeniniu keitikliu (Picoscope ADC 212/100, Picotech Ltd.), funkcijų generatoriumi (Hameg HM8131-2, Hameg Instruments GmbH), analoginiu Doplerio prietaisu (806-C, Parks Electronics Inc.) ultragarsiniais keitikliais ir realiais tiriamaisiais objektais. Studentai, eksperimentuodami su mūsų sukurtomis į problemas orientuotomis sistemomis, ugdydys savo gebėjimus kurti šiuolaikines modulines, lanksčias ir išplečiamas sistemas. Il. 4, bibl. 7. (anglų kalba; santraukos anglų, rusų ir lietuvių k.).