Adding Tactile Information to Remote & Virtual Labs

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Abstract - **This work presents different approaches for illustrating one process of determining in the lab the Young Modulus, a material property that describes its stiffness and so is one of the most important properties in engineering design. It describes briefly a classical experimental procedure in a traditional lab, a remote accessed system, a remote & virtual accessed system haptically interacted and finally, a new approach under development, a virtual system with haptic interaction. Along the text some constrains will be discussed and the evolution for this new development will include a short discussion devoted to the increase in capabilities of the virtual experiment when integrating force feedback information and the authors attempt to consider the richness of such a solution compared with others described.**

Keywords - ***Haptic interfaces, Virtual reality, Engineering education, Training, Young's modulus, Remote sensing***

I. INTRODUCTION

The progress of humanity has been strongly based in the learning by doing approach. In Science and in Engineering fields, mainly at undergraduate level, hands-on-activity is fundamental to allow the students to observe, confirm, understand and interpret theoretical laws and effects and to analyze results. In fact, since the earliest days of engineering education experimental activities have always been present in the undergraduate engineering syllabus [1]. Hands-on-activities are also valuable tools to foster active and collaborative practices in student groups, to incentivate discussions, inquiries, answers, reasons and doubts, leading to a higher stage of knowledge and better ability for problem analysis and solution.

Considering the diversity of learning styles and that nothing is applicable to everybody, remote laboratories appear as a distant access to hands-on activity offering tools for inductive teaching and learning in the student centered teaching and learning method [2] and extending to the learners new possibilities of using lab equipment without location and time restrictions. They also disseminate resource sharing in hands-on activity, promoting collaborative use [3], even at international level [4, 5]. Nowadays, many universities already have laboratory environments through the web and consortia have been established involving different University lab partners. This is the case of the "Library of Labs" (LiLa) Project sharing the contribution of "eight universities and three enterprises, for the mutual exchange of and access to virtual laboratories (simulation environments) and to remote experiments (real laboratories which are remotely controlled via the internet) [10].

The main objectives of remote labs may be summarized as follows:

- To be used as complement, in a b-learning approach, increasing the experimental offer;
- To attenuate the contact time reduction of current educational politics;
- To permit, as much as possible, a personal contact and system exploration by observing the system response to the user actuation;
- To improve student autonomy according to Bologna recommendations;
- To supply the experimental results to the student in order to permit later data processing;
- To promote the discussion and analysis of results as well as their correlation with theoretical concepts;
- To contribute, within large classes, for a better adequacy to the diversity of learning styles;
- To contribute for spreading experimental activities;
- To improve resources for lifelong learning activities;
- To contribute for better resource management.

In remote labs, additional information, as the case of real time video from the remote experiment is essential for increasing realism.

Important contributions are also expected from virtual labs built with high level of realism and accuracy. A special focus should be directed to excellent replicas from real systems, as is the case of 3D VRML models of laboratory equipments where users may pan, zoom and tilt perspectives, interact with equipments, experiment and visualize effects and results and use multiple camera visualization angles. Applications like wind tunnels [6], a virtual refinery [7], a Michelson Interferometer [8] and a structural mechanics virtual tool [9] are examples of this type of approach.

In a virtual lab or experiment the user interacts remotely or uploads a developed application based in a system model. This brings higher flexibility and complete freedom, inherent to the virtual essence and it is not constrained to a remote real set-up, and to all the limitations coming from its real condition and associated software instability and internet connection limitations (velocity and response latency, browsers incompatibility, fire wall policies,…) .

So, a virtual experiment well structured and designed could be of higher cognitive stage for learning/training purposes [11]. If it is designed focusing on the main learning/training desired goals it will be the bridge to the real system overcoming an important gap – to become familiar and confident with specific systems to be later used at real labs. This is the case, as it was experienced with the virtual Michelson Interferometer (MI) referred above when tested with a group of students by first using it and then latter they had the opportunity of using a real MI in a hands-on activity at the lab. The interferometer is a sophisticated system for regular students, very sensitive to be tuned and handled. The experience was done with mechanical engineering students at the Faculty of Engineering of University of Porto. The results were very positive [12]. The same is important to address when the remote lab is based on dangerous or very expensive systems. Then they can overcome a big step, from the text book to a friendly user interface following the real behavior and giving a "real" perspective of it. And finally, every user is able to use it, instead of merely observing one colleague in the group doing it. Of course, in our point of view, all this approach is of significance if it could be used in a complementary way.

Going back to remote experiments or labs, it is well known that they currently incorporate video information, bringing more realism to the remote condition. In fact, any additional sensorial information is desired for trying to enrich their remote condition. Then, when suitable, the integration of haptic devices should bring new perspectives to remote and labs, adding crucial sensorial information of force feedback and tactile types. In terms of force feedback it is possible to simulate object hardness, weight and inertia, while tactile feedback deals with surface contact geometry, smoothness, slippage and temperature [13].

Haptic devices have been used in education/training for processes depending on touch to get a better understanding of some phenomena or subjects. They can improve simulation realism and offer to students interaction output similar to that performed in real conditions.

Several areas have used haptics to improve educational practices. Haptics for elementary school activities was the subject of a research that intended to collect feedback and suggestions when a Phantom device was used to simulate Physics phenomena [16, 17]. The results of the study only suggested an improvement in learning activities and the potentiality in the use of the technology. Grow *et al.* (2007) [18] reported their experience in incorporating haptic devices and simulations into undergraduate, graduate, and grade school curricula. Their goal was to encourage students for interdisciplinary education and innovation. However, some researchers argue that the use of haptics for learning activities must be analyzed to avoid the focus of student in the device [19]. This is important since the use of haptics must improve the learning process and not add difficulty to this process by the use of an uncomfortable and hard-to-use device. Thus, the option for a haptic device model and also its use must make sense in the context of each problem approach.

In the next section three experiments related with the determination of Young Modulus will be briefly described. The first case is a pure remote experiment. The second is a mix of a remote and a virtual experiment integrating a haptic device. Finally, it is described a third one purely virtual but integrating a haptic interaction in which, in the authors believe, the main concept will be more efficiently conveyed.

II. Remote & Virtual labs

The Young Modulus of a material is a property that describes its stiffness and so is one of the most important properties in engineering design. The information about mechanical material characteristics is essential in several engineering areas, namely in the mechanical engineering field. At the Faculty of Engineering of University of Porto (FEUP) there is a course on Instrumentation for Measurement in which students do different tasks at the lab in around 63% of the course lecturing time. In a complementary approach to some a lab sessions where students use traditional hands-on activity, there is some remote experiment available where students can go back to look at the subject in a different but convergent perspective or just to go back to it and even with some new features for being explored. So, in the case of the determination of a Young Modulus based in the use of a beam instrumented with resistance strain gages and under bending tests, several approaches were built. In the next paragraph it will be described the remote lab for Mechanical Material Characterization.

A. A remote lab on Mechanical Material Characterization (MMC)

The remote experiment is divided into two parts: the experimental set-up and the user application. The set-up was specially designed for the MMC remote lab. The material beam is loaded by a coil type linear motor in a closed-loop control system. A miniature load cell provides the force feedback of the beam when loaded. The strain measurement is performed by strain sensors of resistance type. The interface hardware and software for data acquisition are from National Instruments.

In the user interface there are three areas. The main area makes available user input actions, either of automatic or manual type, output data either in graphical or in numerical form, as well as other additional information. In the top right-hand corner there is real time video information from the real system. Below it there is a picture of all the remote accessed experimental set-up [14] (Fig. 1).

This remote experiment is particularly adequate for using additional sensitive information and because of that the authors have been concentrating several efforts in order to integrate haptic interaction in it. In a first instance an application was designed at the Federal University of Paraíba, Brazil, and work was done in order to access it from there to the experiment in

Portugal [15]. Internet latency brought difficulties and then it was decided to design a new interface for being used by students, locally (at FEUP). The application and its use are described in the next topic.

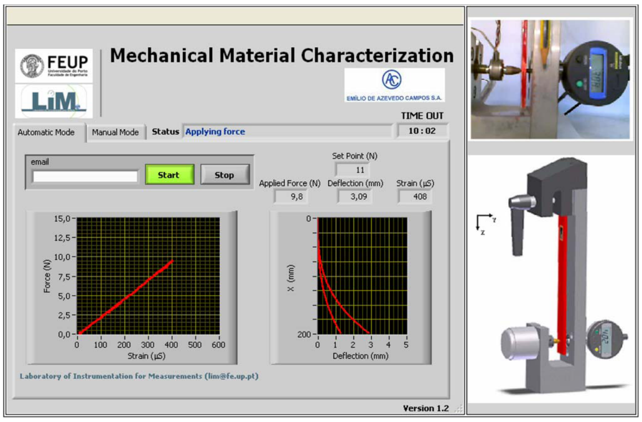

Fig. 1 - User interface.

B. A remote and virtual lab with haptic interaction

In the present application the experiment with haptic interaction can be divided into three main parts: the remote experiment, the remote server application and the haptic interface device. This device is a Phantom Omni model, by Sensable, Inc. (USA). The haptic device is controlled by a local software application – client. A remote application – server – controls the remote set-up. The client user application provides a graphical user interface with different areas. In the right side there is a virtual replica of the set-up. In the left side, on the top, there is the remote system starting up button, in the middle area is displayed the system real-time video, and in the lower corner there is available to the user the applied load information and the corresponding strain values received from the server (Fig. 2).

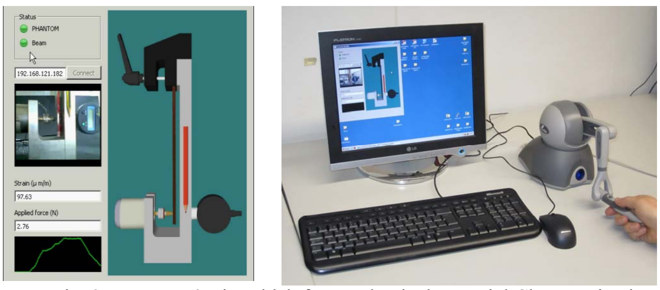

Fig. 2 - Remote & virtual lab for Mechanical Material Characterization.

Even using the experiment in the FEUP Campus, it has been evident that there is very short delay between input load and the observed real system reaction. And, obviously, all other problems associated with remote labs are present.

A next step has been designed and is now under development considering a pure virtual version of this experiment. And, due to its virtual character, it is going to be possible to make it much more flexible, avoiding all the internet and system hardware constraints.

C. A virtual lab with haptic interaction

In the present application the experiment with haptic interaction can be divided into two main parts: the virtual model application being also the user application and the haptic interface device. The user application provides a graphical user interface with three main areas. In the right side there is a virtual replica of the set-up. In the left side, the user will have a selecting option of different beam materials, and in the lower area there is available the user applied load information and the corresponding strain values received from the virtual model, as well as the time evolution of the applied load for guiding user actuation. For example, if the user wants to determine the Young Modulus for each or any material there is a measurement procedure protocol that may be followed and this information will have great relevance to the user actuation.

The applied force, the virtual model reaction and the force feedback to the user through the haptic device are computed using the beam physical model. The application has been developed in C++, using the "QT" framework for the graphical interface. Fig. 3 has a first version of the interface, although it is still under adjustment and testing.

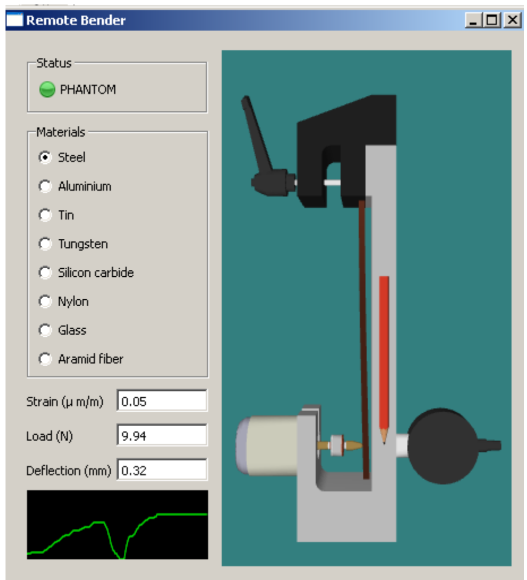

Fig. 3 - Virtual lab for Mechanical Material Characterization.

In any case the systems A and B previously described have been used for evaluating student feedback from exploiting, additionally to their traditional lab classes, the remote experiment and remote and virtual experiment integrating the haptic device in such type of measurement.

III. Short Report on Student Reactions

In order to observe the students impressions when using the haptic experiment, a set of three questionnaires was designed and applied to students of FEUP. The first questionnaire was answered by a set of students that only attended traditional lab sessions. The second questionnaire was answered by students that attended the traditional lab sessions and also used the remote laboratory. Finally, the third group attended the traditional lab sessions and the remote and virtual experiment with haptic interaction.

It was defined that some questions must be present in all the three questionnaires which were added with other questions specific about each performed experience. The similar questions allowed comparing groups and the specific questions to know the variability inside the groups.

The questions were of multiple choice type and students could choose more than one option according to their opinions. Some questions specifically ask students to provide impressions when using remote lab and Remote and virtual haptic lab. Suggestions were also collected in order to improve next version of the systems. The sample for each questionnaire was composed by 29, 27 and 30 students, respectively.

The preliminary results obtained pointed that the use of the remote lab help 82,14% students to better understand the experiment and that the use of haptics allow to 77,42% to understand the forces associated to the experiment. Additionally, approximately 78% of students report comfort and easiness in the use of the haptic device.

IV. FINAL COMMENTS

The new application under development will be available for being used anywhere for everyone without any other restriction except the requirement of an Omni Phantom haptic device. The experiment will be of higher pedagogical interest because it will be easier to be used and will put in real evidence not only the measurement procedure, the physical correlations between parameters but also, the reactions from different materials, from traditional ones to new generation materials, like for instance composite materials. Moreover, it is always possible to integrate new materials in the application. It is also important to note that, in the final version of the application, the color to be used for the beam of a particular material has to be chosen according with its current aspect. As explained before the experiment helps the students to become familiar with the lab procedure for evaluating the Young Modulus of a material. Because it inherent virtual environment the addition of improved features will be always possible opening the possibility of a really rich virtual experiment.

It is important to mention that the preliminary evaluation of the experience did not show differences with statistical significance. However, the students told that both technologies, remote lab and haptic lab helped them to understand the subject. The expansion of the sample and other studies are being conducted and planed.

The application under development will be under similar evaluation in the second semester of the academic year 2010/2011.

ACKNOWLEDGMENT

The authors wish to acknowledge the support provided by the System Integration and Process Automation Research Unit at the Mechanical Engineering Institute (IDMEC/Polo FEUP) and by the Faculty of Engineering of University of Porto. The authors also thank the Laboratory of Technologies for Virtual Teaching and Statistics - LabTEVE, in the Department of Statistics of the Federal University of Paraiba (UFPB). They want to acknowledge the commitment of the team at the Laboratory of Instrumentation for Measurement at FEUP, where all efforts have been made to carry on the good maintenance conditions for the REMOTELAB at FEUP, http://elabs.fe.up.pt.

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