Remote Experimentation: Improving User Perception Using Augmented Reality

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Introduction

The possibility to conduct live experiments on real setups is a key pedagogical element which enables teachers to give life to the subject matter. In order to avoid moving the experimental setup in the classroom, or to overcome the difficulties of accessing laboratory facilities at any time, it is useful to provide an interactive and remote access to such facilities. A good quality for the visual feedback provided to the user is a key to enhance the user perception of the remote system. A multiplatform client-server solution based on personal computers, which share information through the Internet, has been designed to serve this paradigm. LabVIEW is the ideal candidate to provide the interoperability and the advanced tools required for both the communication and visualization purposes.

The Laboratory Environment

Physical setups available for studying motion control are composed of a real system– in our case an electrical drive or an inverted pendulum (Fig. 1) – connected to a Power Macintosh via an acquisition board (NI PCI-1200). The control software which pilots the real process locally is a Virtual Instrument (VI) built using LabVIEW. An in-house real-time kernel [1] extends the LabVIEW capability and guarantees high speed and accurate pace. The VI provides a complete interface between the user and the real process. It is used to generate excitation signals and observe corresponding responses. The main concept of such an interface is to provide a general view of the real process evolutions, and to allow full control of the operations.

Figure 1. a) The electrical drive consists of DC motor equipped with a built-in tachometer and a potentiometer connected to the motor axle for measuring the angular position. b) The 4 meters long inverted pendulum is equipped with two absolute digital encoders, the first one measuring the cart position and the second one the arm angle.

The Communication Architecture

Given its fully computer-based implementation, the laboratory environment described can be easily expanded for remote manipulation [2]. The main concept in turning the locally-controlled setup into a remotely-controlled one consists in moving the user interface away from the experiment. Two distinctive parts result: the remote client and the on-site server (Fig. 2).

- The remote client is a computer equipped with the user interface functionalities. The client software allows the users to observe and to act on the remote experiment.

- The on-site server is the computer located near the real process and equipped with the hardware interface to the sensors and actuators. The server software receives the client commands and transmits them to the real process. It also returns the state of the real process to the client.
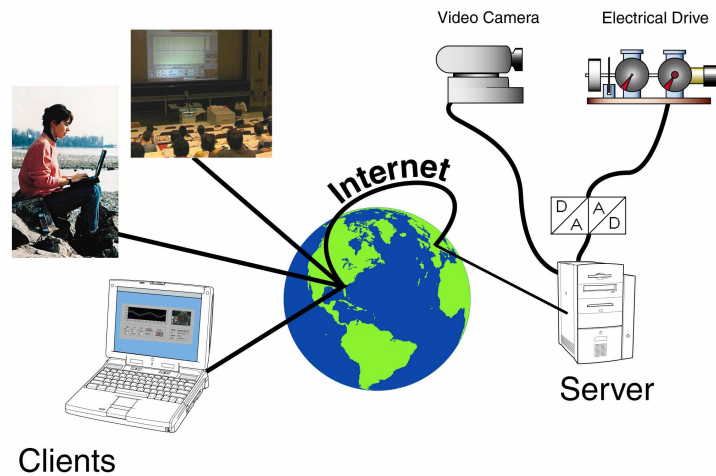

Figure 2. The client-server architecture.

Visual Perception

The visual perception is provided by the Graphical User Interface (GUI). A cockpit-like metaphor, similar to the local one, is used to present the different information to the user (Fig. 3). The GUI is splited into four areas. The scope area (1) enables the user to follow the time evolution of all signals relevant to the experiment (for example the internal states of the controller). The visual area (2) provides a video image of the real process enhanced with the virtual representation (VR) of the process. The user is allowed to modify the parameters (3) of the controller as well as other adjustable characteristics of the experiment. The 'hand' button is meant for remotely perturbing the physical system. The administrative area (4) manages the different connection stages such as user login/logout.
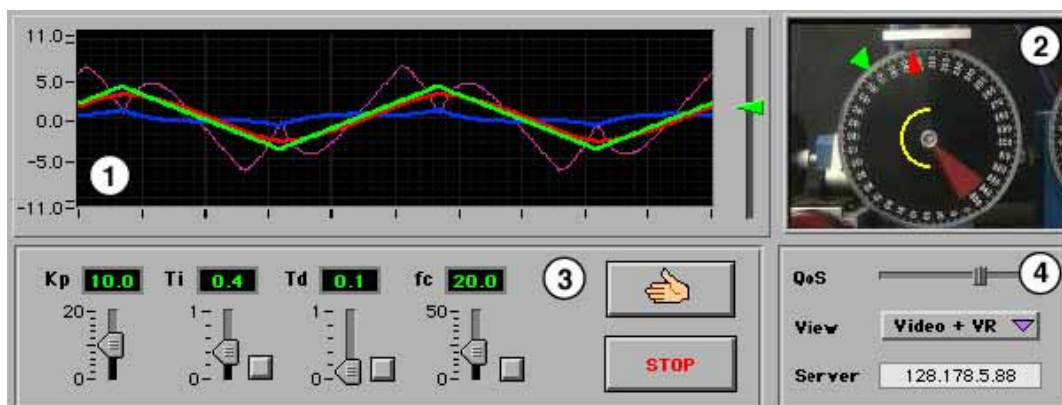

Figure 3. The Graphical User Interface at the client side.

Augmented Reality

Visual feedback is especially well suited for mechatronic processes. Special attention has been made to providing the user with not only the video image of the process but also by superimposing other information such as the virtual reality representation of the physical system, resulting a composite image called augmented reality (Fig. 4). The virtual image is derived from the measurements made on the real system, whereas the video image comes from the video camera. The difficulty to synchronize theses two representations is largely compensated for by the benefits resulting from their combination. The virtual image is also useful when the available bandwidth is small. Instead of using a large portion of the available bandwidth with the video image, only a few (1 or less) video frames per second are sent. The missing dynamic of the video is compensated for by the animation of the virtual representation.

One can observe that the video image carried far more information than the virtual representation. Through the real image, the user can get a feeling for the real setup. This is essential in remote experimentation. The video image also gives environmental information which is undetectable using the virtual image, as for example a wire running across the moving parts of the electrical drive.
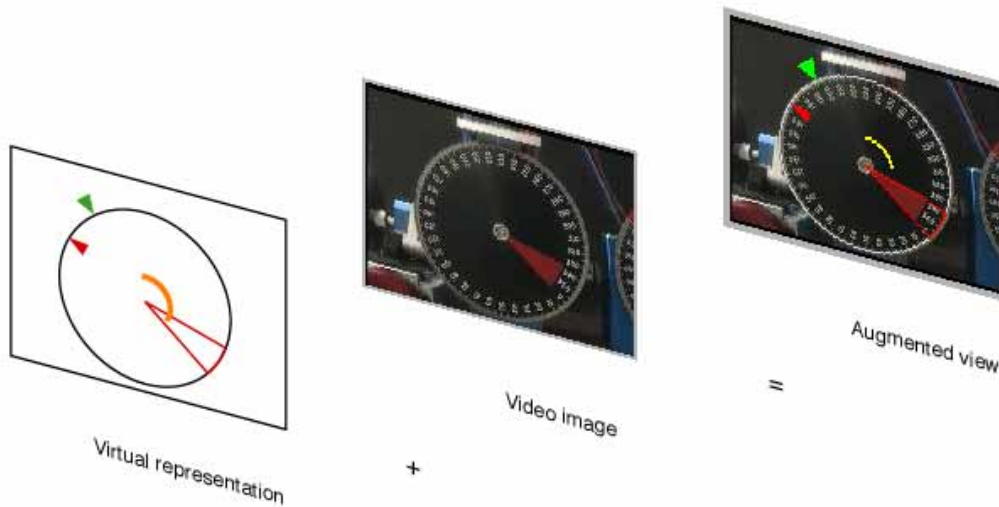

Figure 4. The Augmented view is made of the video image enhanced with a virtual representation driven by the measurements made on the real system.

Another example of augmented view is shown in the next picture where the user can remotely push the inverted pendulum as visualized by the virtual hand (Fig 5). The virtual representation is also useful for adding information which are not visible on the video view. As for example the force applied to the cart (*represented as a variable length horizontal line in Fig 5*).
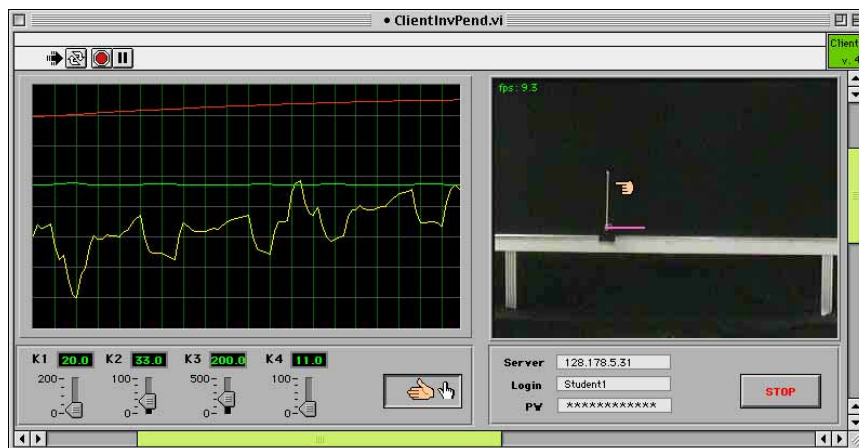

Figure5. User interface for the inverted pendulum.

Video Frame Grabber for LabVIEW

A set of VIs were developed to grab images coming from a video camera. These VIs are based on QuickTime (QT). They can use any input source supported by QT provided that the corresponding *vdig* (driver) exists. The image is displayed in a LabVIEW picture indicator. These images can be compressed in JPEG format (other formats are possible) before being sent across the Internet. On the receiver side the images are first decompressed and then displayed. Figure 6 presents a simple video grabber with an enhanced view of the real system. The image is updated 5 times per second.
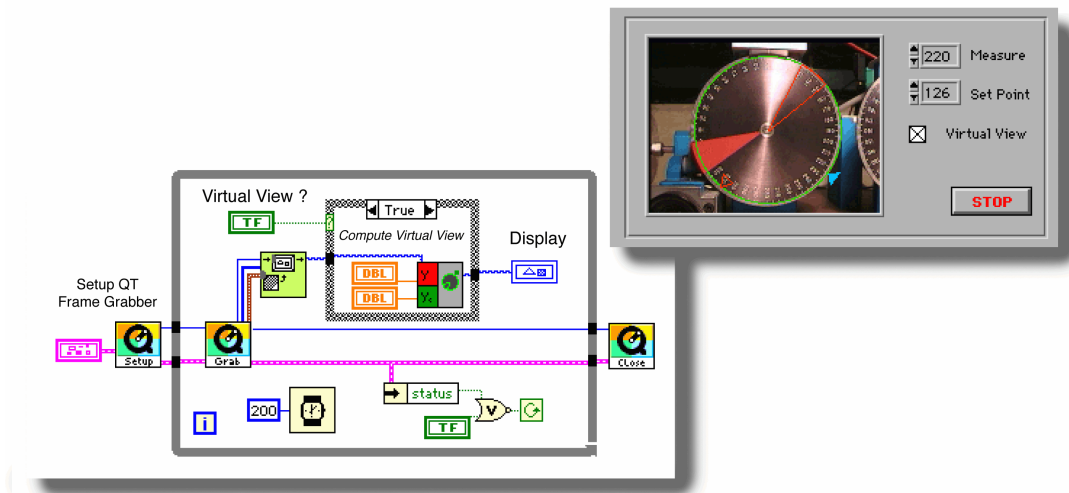

Figure 6. The QuickTime grabbing VIs.

Compared to the use of a separate software for broadcasting the video images, the proposed approach enables the synchronization of the various representations both in space (if the camera is re-oriented) and in time (if the video images transmission time is different than the one for the VR animation).

Conclusions

Compared with experimentation in virtual reality, remote manipulation on real processes is easier to implement and more versatile. In fact, adding or selecting another physical setup does not involve the elaboration of complex mathematical models and graphical representations.

Remote experimentation is not limited to education. In research and industry, remote accesses also represent an interesting opportunity to meet the growing need of scientists who wish to share unique or expensive equipment and to enable support engineers to operate immediately at customer facilities.

Finally, an efficient integration of both real video and virtual representation provides the users with the necessary level of interaction required in remote experimentation.

References

Visit the remote experimentation web site at http://iawww2.epfl.ch

[1] Salzmann Ch., D. Gillet, R. Longchamp, and D. Bonvin, "Framework for Fast Real-Time Applications in Automatic Control Education", *4th IFAC Symposium on Advances in Control Education*, Istanbul, Turkey, 1997.

[2] Salzmann Ch., H. A. Latchman, D. Gillet, and O. D. Crisalle, "Requirements for real-time experimentation over the Internet", *International Conference on Engineering Education, ICEE'98*, Rio de Jan