2006-2354: BROADCASTING NUCLEAR ENGINEERING LABORATORIES - VIDEO AND DATA - IN REAL-TIME OVER THE INTERNET

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Broadcasting Nuclear Engineering Laboratories—Video and Data—in Real-Time over the Internet

Abstract

A real time, distance lab module is developed and implemented in the Department of Nuclear, Plasma and Radiological Engineering at the University of Illinois at Urbana-Champaign. This internet based system allows remote personnel to watch the experiments, acquire data, and interact with on-site personnel. The e-lab broadcasts not only the live scenes of laboratory and experiments, but also the real time data and plots being measured and displayed in graphical and other formats. Moreover, use of LabVIEW's *remote front panel* feature allows communications between the local lab and remote client so that, if permitted, remote client can control part or all of the experiment in real-time.

Keywords: *Broadcast, Distance education, e-Lab, Internet, LabVIEW*

1. Introduction and background

The internet and world-wide-web has become an indispensable part of modern day education, supplementing existing classroom education and also supporting web-based courses and programs. Though the distance learning programs continue to expand, real-time broadcasting of engineering *laboratory* courses is still in its infancy. In addition, for expensive and/or dwindling experimental facilities – such as training and research reactors – distance lab modules may become an economic necessity. While distance lab modules - just like distance courses - may never be as meaningful as their in-lab counterparts, it may be possible to make them somewhat realistic. Moreover, in some ways, distance-labs (or e-labs) might actually provide a more

meaningful experience than presence in a crowded lab in the back of the room. Also, embedded multimedia features along with interactive simulations will allow remote users to visualize and grasp different dynamic concepts and that, in turn, can promote active learning.

Recently, several efforts have been made worldwide towards implementation of web-based laboratories. Rohrig and Jochheim[1] presented a Virtual Lab approach based on client/server architecture written in JAVA to remotely access control engineering experiments at the University of Hagen, Germany. Gurocak[2] presented a novel method for distance delivery of a manufacturing automation laboratory course among different campuses in Washington State University (WSU) by linking them with an interactive TV system called WHETS. The limitations and goals of their approach are somewhat different. For example, it is desirable and necessary to have the experimental set up at each remote location, and all students must assemble in one of these remote labs. Moreover, there is little interaction with the instructor and little flexibility in controlling the experiments from remote sites[1-2].

Efforts are also underway in some nuclear engineering departments towards development of distance lab capabilities[3-8]. Some of these include development of remote interface for Penn State's TRIGA reactor[3] and for PULSTAR reactor at North Carolina State University[4].

A real time, distance lab module is being developed and implemented in the Department of Nuclear, Plasma and Radiological Engineering at the University of Illinois. It is an internet based system that allows those at remote sites to watch the experiments, acquire data, interact with on-site personnel, and if permitted, even control part or all of the experiment. With network cameras (webcams) and LabVIEW, the system can broadcast not only live scenes of the laboratory and experiments, but also the real time data and plots being measured and displayed in graphical and other formats. Moreover, LabVIEW also allows communication between the local lab and remote client so that remote client can obtain full control of the experiments. Building on our previous work[5], we here report recent developments in our efforts to develop a framework that exploits mostly off the shelf technology to develop an e-lab module for distance education.

2. Methodology

Figure 1 shows a schematic diagram of the system. It has four components: local lab; LabVIEW; network camera; and remote client. "Local lab" includes experimental setup at the local facility and personnel carrying out the experiment. "LabVIEW" is National Instrument (NI) software package that is capable of signal acquisition, analysis, and data presentation. It also has built-in capability for web-broadcasting. "Network camera" is a digital network camera installed in the lab that can capture the video and audio of the experiment and transmit them live over the internet. "Remote client" may be any computer connected to the internet.
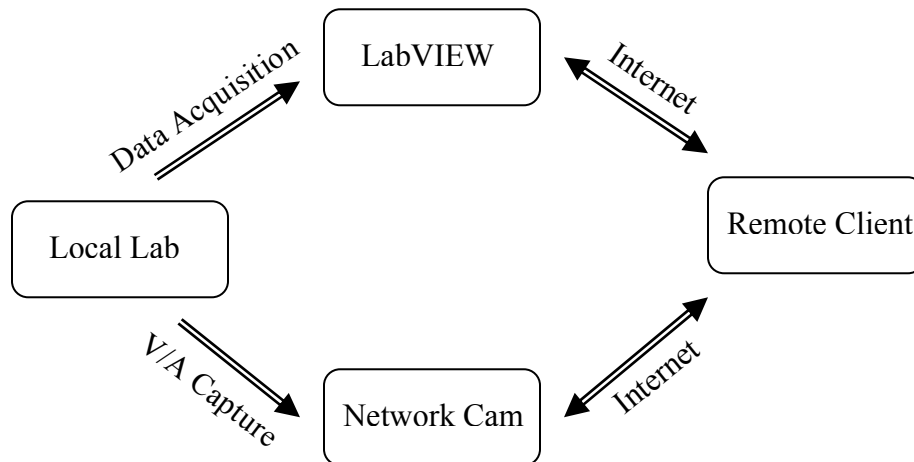

Figure 1: Distance Lab Schematic Diagram[5]

As mentioned above, network camera broadcasts live scenes of laboratory and experiment, while LabVIEW broadcasts real time data and plots being measured and displayed in graphical and other formats. Moreover, LabVIEW also allows communications between the local lab and remote client so that remote client can be given full access to control the experiment.

Implementation of these capabilities requires certain hardware and software. For example, the experiments must have data acquisition hardware capable of communicating with LabVIEW, which must have the data acquisition driver installed. LabVIEW applications are usually

experiment-specific. Broadcast and web publishing of data require that the computer running LabVIEW is connected to the internet. Web-casting requires a network camera that is viewable and controllable through a standard web browser. The camera should have fast frame rates, high resolution, large bandwidth, and preferably a built-in microphone. The remote client needs a computer with multimedia and internet. It needs installation of some runtime engines (which are freely available) to view the live camera view and to view the LabVIEW webcast.

3. Equipment description

3.1. Local Lab

3.1.1. Experimental set-up

A boiling heat transfer experiment operational in the Department of Nuclear, Plasma and Radiological Engineering—to measure heat transfer coefficient before, during and after film boiling—has been modified for the e-lab demonstration and tested (see Figure 2). The purpose of this experiment is to acquire physical understanding of the phenomena that are characteristic of various boiling regimes. A metal sphere is heated to nearly 420 $^\circ$ C, and then submerged into a pool of near boiling water. There are two thermocouples embedded in the sphere. One is placed very close to the surface of the sphere and measures the surface temperature, T_s. The other is located at a selected radius inside the sphere and measures inside temperature representative of sphere's average temperature, T_{avg}. This value, when measured over time, can be used to determine the heat flow rate from the sphere, Q

$$Q = \rho C_p V \frac{dT_{avg}}{dt}$$

where V is the volume of the sphere.

Figure 2: Experimental set-up. A hot sphere (near 420 C) dipped in near boiling water.

The heat transfer coefficient, h, is obtained from Newton's law of cooling, which is

$$h = \frac{Q}{A\Delta T}$$

where A is the area of the interface and ΔT is the difference between surface temperature and the bulk fluid temperature.[9] As the hot sphere is dipped into the pool of water, it first leads to film boiling where a vapor film is clearly visible around the sphere. Heat transfer rate during this stage is low. Sphere's surface and inside temperatures slowly decrease with time. As the vapor film breaks down and water touches the hot sphere, there is violent and vigorous boiling as the film breaks down and cooler water comes in contact with the hot sphere. There is rapid heat transfer and the temperature over a few seconds drops significantly. By repeating the experiment with a copper and a steel ball, the relative difference between the surface and inside temperature is also indicative of ball material's thermal conductivity. Besides the post experiment analysis of data, *simultaneous* observation of different stages of boiling (a view of the experiment) and associated thermocouples readings (data being measured) is an instructive experience of this experiment, which makes it an excellent candidate for this prototype e-lab.

3.1.2. Data acquisition instrument

The experiment uses a USB-based temperature measurement device USB-TEMP (Measurement Computing Corp.) that provides eight differential temperature input channels and supports all of the common sensor-type thermocouples, RTDs, thermistors and semiconductor temperature sensors. It provides temperature measurement flexibility as each channel can monitor any of the supported input types. Thermocouples' input is fed into USB-TEMP, which is then connected to the PC via a USB port. (See Figure 3.)

Figure 3: USB-TEMP – Measurement Computing Corp. product[10]

The device also has an open thermocouple detection feature which lets user detect a broken thermocouple. Moreover, an onboard microprocessor automatically linearizes the measurement data according to the sensor category. In addition, it is a standalone plug-and-play module which draws power from the USB cable i.e. no external power supply is required.[10]

3.2. LabVIEW (<u>Lab</u>oratory for <u>V</u>irtual <u>I</u>nstrumentation and <u>E</u>lectronics <u>W</u>orkbench)

LabVIEW is a graphical programming language, developed by National Instruments, with built-in tools designed specifically for measurement and control. It is quite similar to traditional programming languages like FORTRAN or C—it allows variables, data types, looping, sequencing structures, etc. It provides very efficient and up-to-date tools for acquiring, analyzing and presenting measured data.

Each program in LabVIEW is called a Virtual Instrument (or VI), which is a primary building block of the application and it allows modularization of the code for efficient design and handling. Each VI is composed of two main components; the front panel and the block diagram. The front panel of the user interface is created by dragging and dropping controls and indicators from the control palette, which are the interactive input and output terminals of the VI, respectively. Controls are knobs, pushbuttons, dials and other input devices. Indicators are graphs, LEDs and other displays. Every front panel control or indicator has a corresponding terminal on the block diagram. The block diagram contains the graphical source code. In addition, the block diagram contains functions and structures from built-in VI libraries. Wires connect each of the nodes on the block diagram, including control and indicator terminals, functions and structures. When a VI is run, values from controls flow through the block diagram, where they are used in the functions on the diagram, and the results are passed into other functions or indicators.

Moreover, a feature called *remote front panels* allows users to view and control the VI front panels remotely from a web browser without any additional programming. Control options, for example, allow the user to switch the display between different quantities being measured. A remote user connected via the web can run an application or check progress. Additionally, several users at different locations can access the VI simultaneously and view "live" updates to the front panel window through any standard browser. However, for obvious reasons, only one client can control the front panel at a time.[11]

Figure 4 shows the front panels of the VI for the boiling heat transfer experimental set-up. Corresponding block diagram is shown in Figure 5.
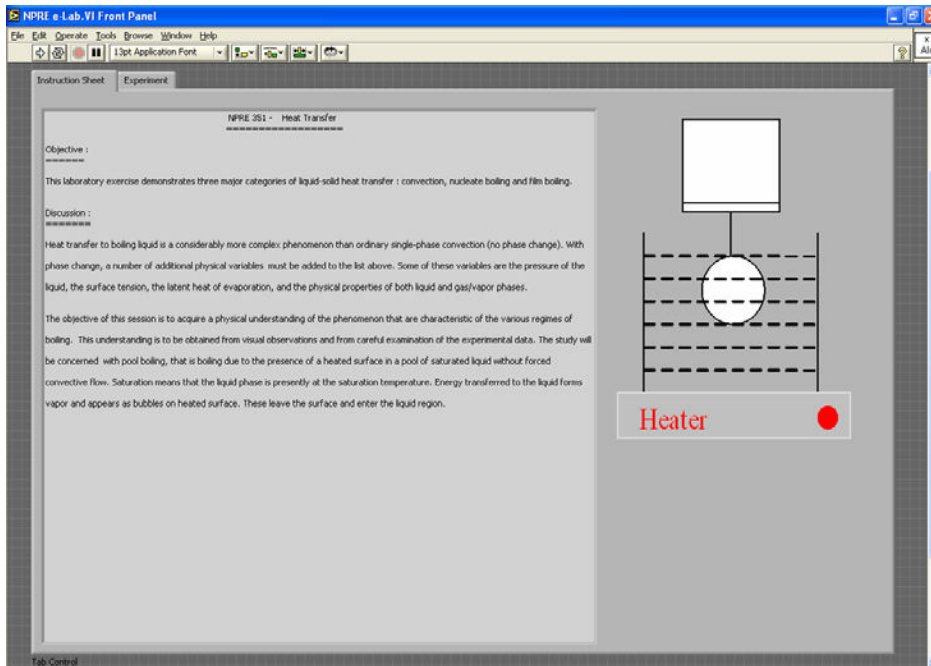
(a)
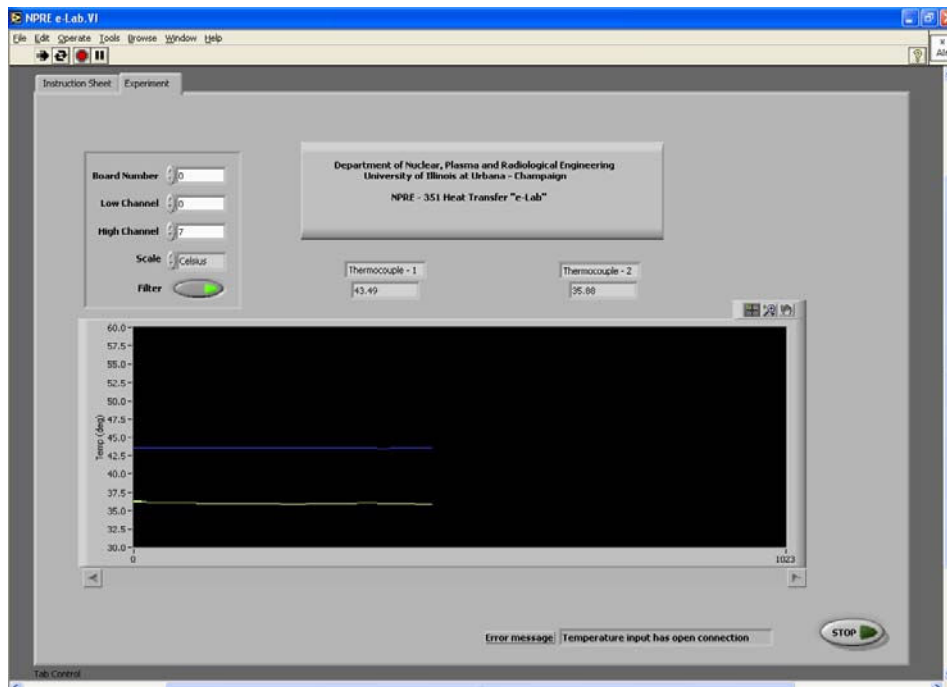
(b)

Figure 4: (a) Front panel of the VI for the boiling experiment. (b) Remotely controlled LabVIEW front panel displaying real-time data.
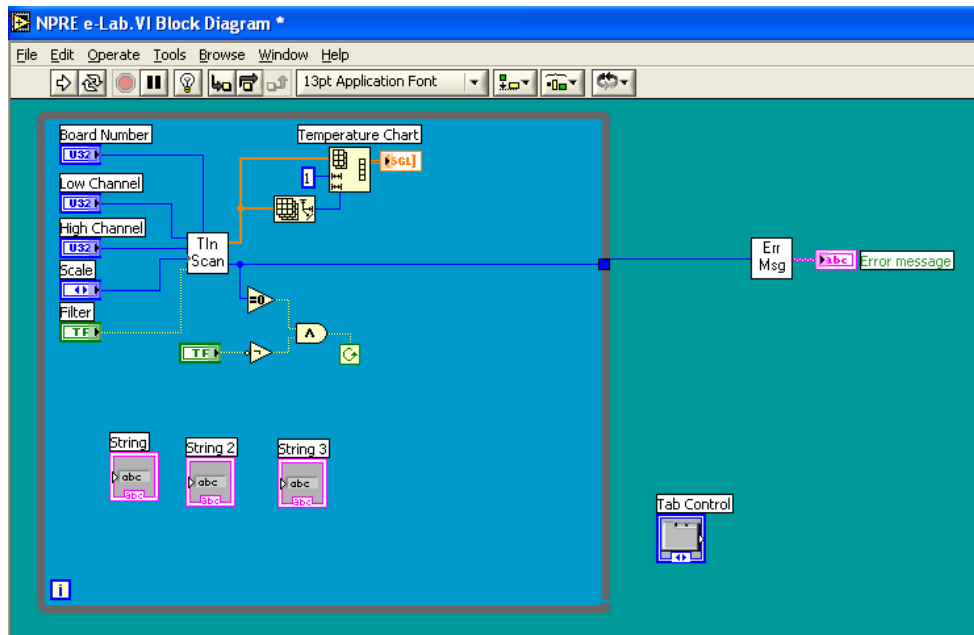
Figure 5: LabVIEW block diagram – graphical source code.

3.3. Network Camera

For video monitoring and web casting, Canon VB-C50i PTZ network camera is used, which is capable of transmitting videos at up to 30 frames per second. The camera's built-in web and FTP server supports 50 viewers to simultaneously access the system. With a *26x* optical and *12x* digital zoom-in feature and 200 ^{o} panning/ 120 ^{o} tilting feature, remote client can virtually access any part of the real-time experiment. In addition, this camera offers two-way audio capability when Canon VB-EX50 Multi-Terminal Module is added. With this module, microphone and speakers can be connected to the camera, allowing remote monitoring of audio at the experimental site. (See Figure 6-7.)
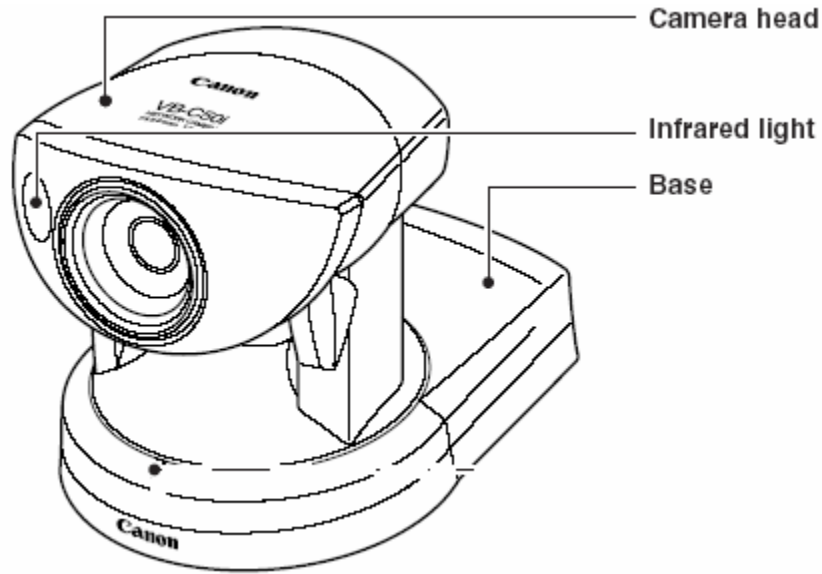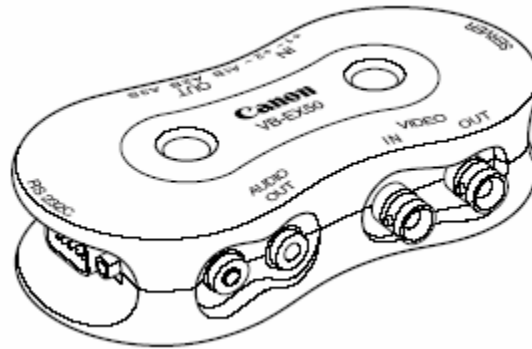
Figure 6: Canon VB-C50i PTZ network camera[12]

Figure 7: Canon multi-terminal module (VB-EX50)[12]

3.4. Remote Client

Remote clients only need a web browser to log into the web sites made available by LabVIEW and the network camera. Remote computers must have LabVIEW Run-time Engine and Java Runtime Engine (JRE) installed. These are free to download from www.ni.com and www.java.com, respectively. Figure 8 shows a network camera view as seen in a web-browser at a remote site. For this particular camera, in addition to pan-tilt-zoom control, remote user can also adjust the background light.
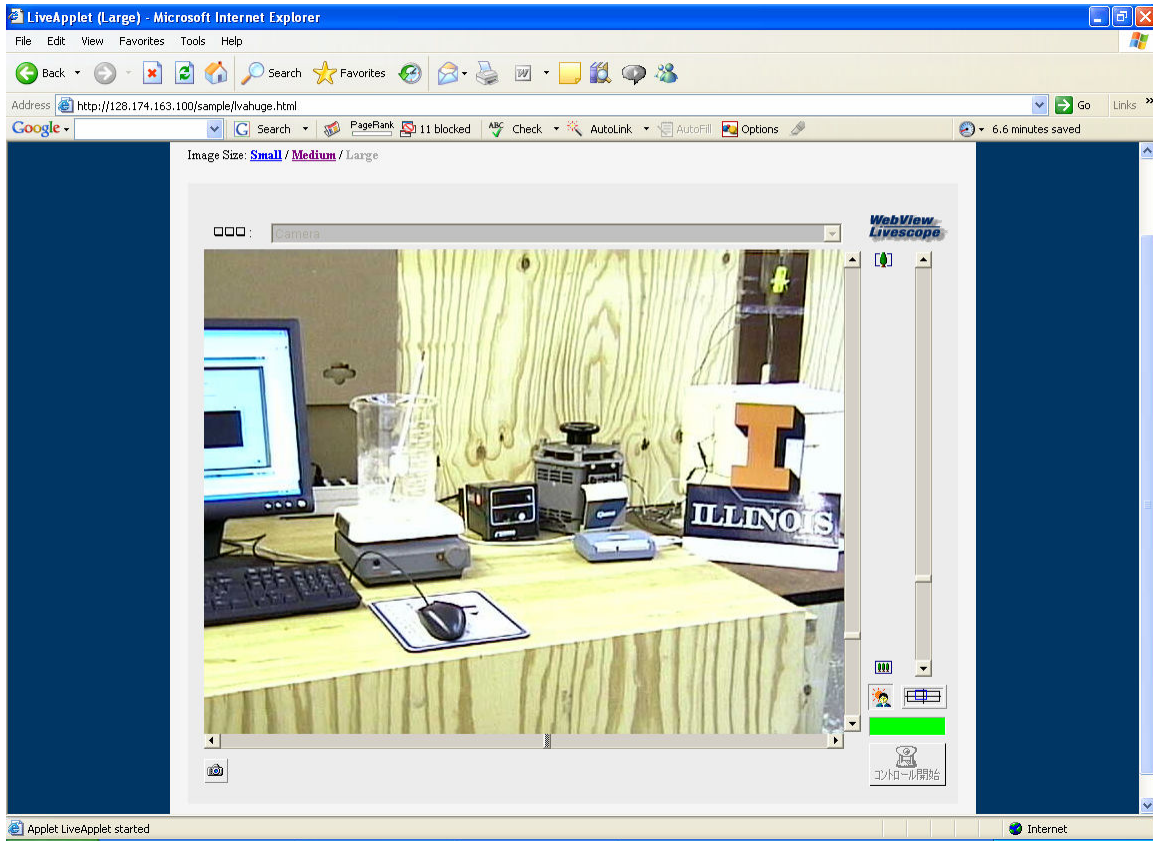
Figure 8: Nuclear engineering distance lab screen shot in a web browser. Remote user can zoom, tilt and pan.

The e-lab described above has been installed and tested.

4. Conclusion

With LabVIEW, internet and computers readily available in most laboratories, web-casting of these labs over the internet to sites around the world can be achieved at a very moderate cost. This prototype e-lab will facilitate reaching a broader audience and enhance distance education programs. It will also help in the development of additional e-labs for more elaborate experiments such as those carried out in a research reactor.

Acknowledgement

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