

## Interactive Virtual Laboratory for Distance Education in Nuclear Engineering

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### Abstract

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 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, e-Lab, Internet, LabVIEW, Distance education*

## 1. Introduction

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 [1]. 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 a passive presence in the back of the laboratory. 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. Building on our previous work, 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 a software package marketed by National Instrument (NI) that is capable of signal acquisition, analysis, and data presentation. It also has built-in capability for web-broadcasting. “Network camera” is a digital camera installed in the lab that can capture

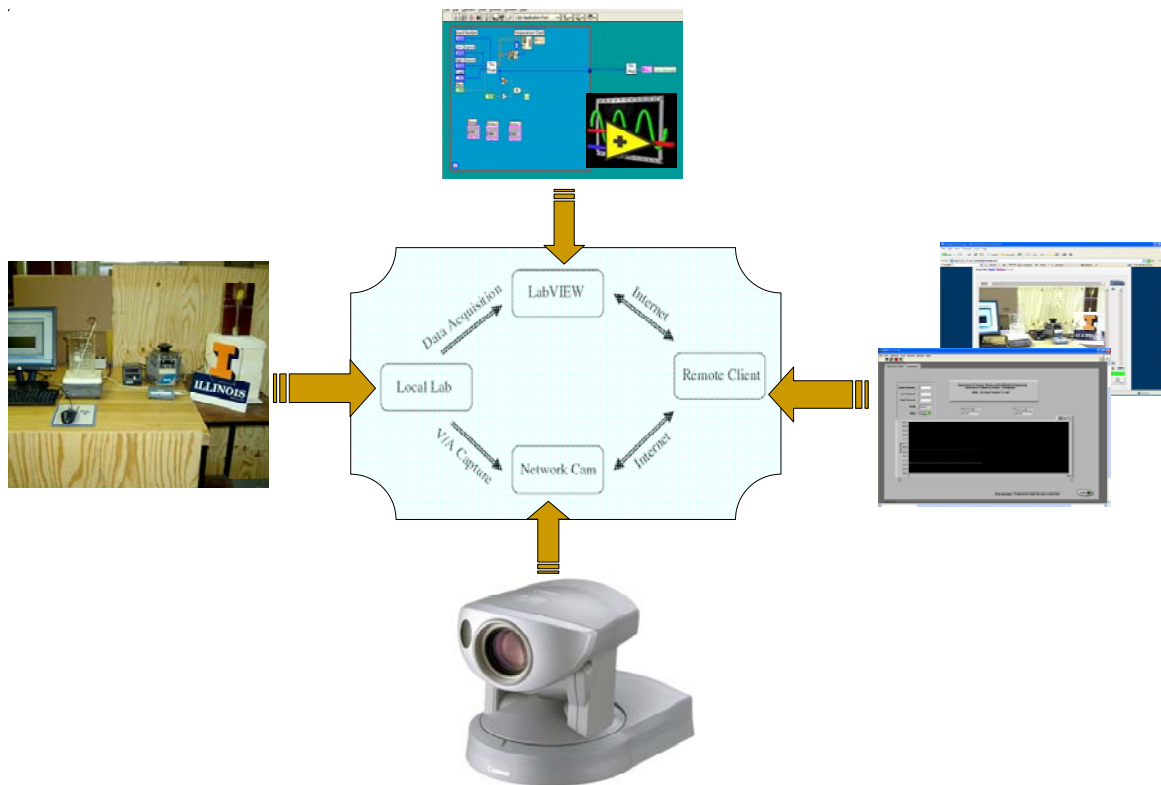
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the video and audio of the experiment and transmit them live over the internet. “Remote client” may be any computer connected to the internet.

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 web-cast.



**Figure 1:** Distance Lab Schematic Diagram

### 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 (or ball) is heated to nearly 420 ° C, and then submerged into a pool of near boiling water as shown in Figure 3. 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. The heat transfer coefficient,  $h$ , is obtained from Newton's law of cooling, which is

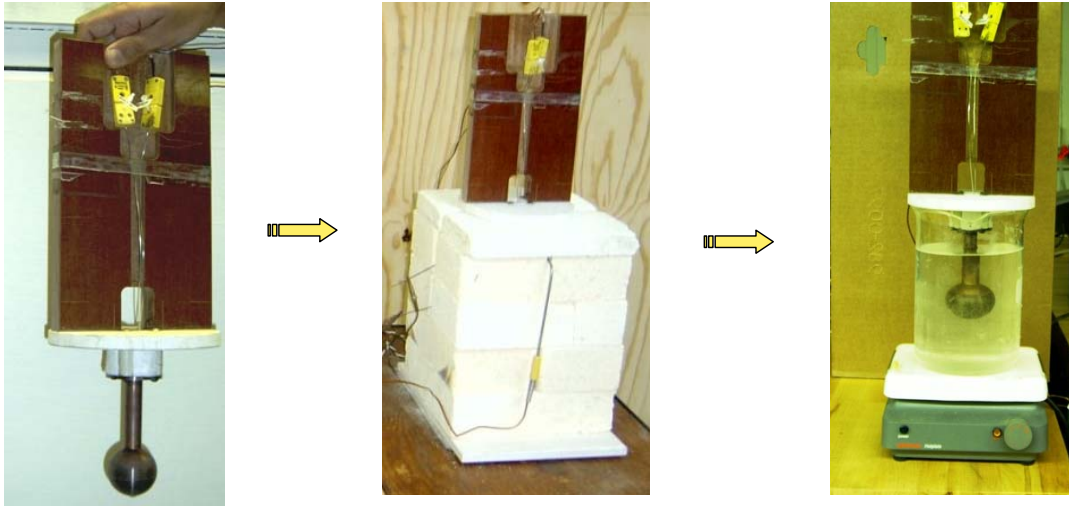
$$h = \frac{Q}{A\Delta T}$$

where  $A$  is the area of the interface and  $\Delta T$  is the difference between surface temperature and the bulk fluid temperature [2].

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.



**Figure 2:** Boiling heat transfer experiment set-up



**Figure 3:** Experimental procedure. Steel or copper ball with two thermocouples (left); ball heated to nearly 420 C (center); heated ball submerged in near boiling water (right)

### 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 (see Figure 4). It provides temperature measurement flexibility as each channel can monitor any of the supported input types [3]. Thermocouples' input is fed into USB-TEMP, which is then connected to the PC via a USB port.



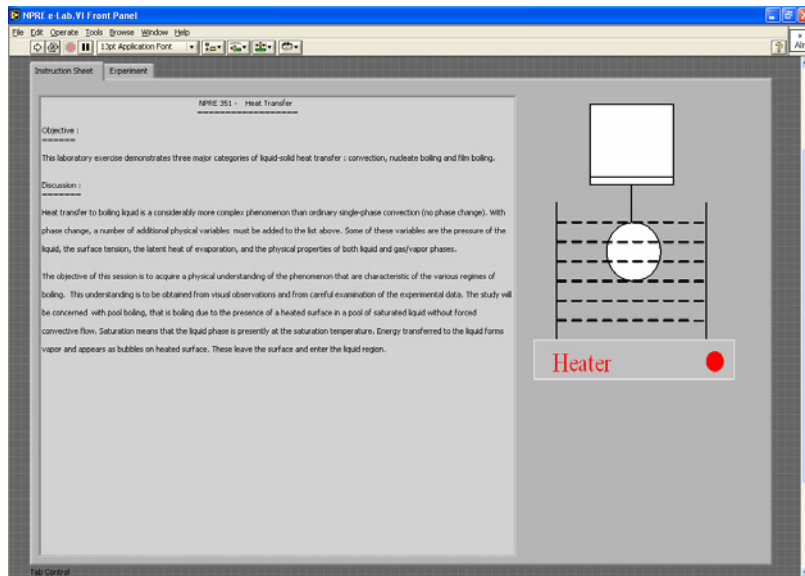
**Figure 4:** USB-TEMP – Measurement Computing Corp. product [3]

This instrument also has an open thermocouple detection feature which lets user detect a broken thermocouple. Moreover, an onboard microprocessor automatically linearizes the measurement data

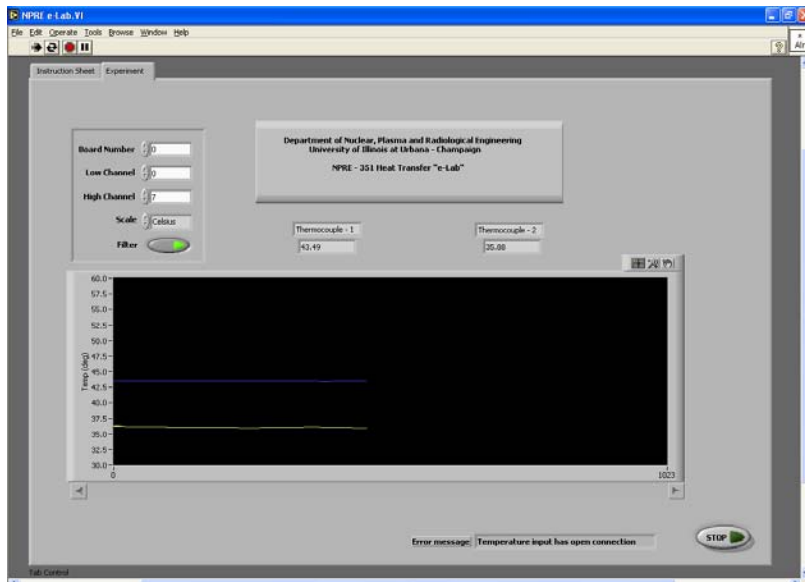
according to the sensor category. In addition, it is a standalone plug-and-play module which draws power from the USB cable i.e. no external power supply is required. [3]

### 3.2 LabVIEW (Laboratory for Virtual Instrumentation and Electronics Workbench)

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 [4].



(a)

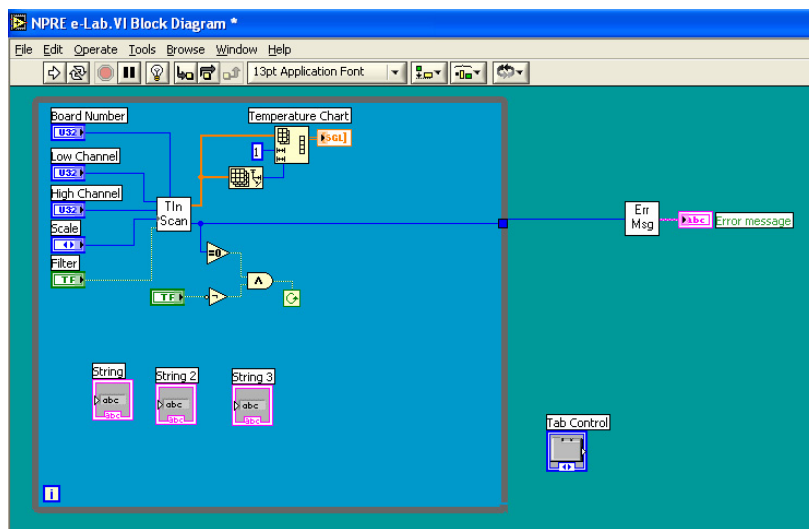


(b)

**Figure 5:** (a) Front panel of the VI for the boiling experiment. (b) Remotely controlled LabVIEW front panel displaying real-time data.



Each interface or window in LabVIEW is called a Virtual Instrument (or VI), which is a primary building block of the application and 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*, *switches*, *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 [4].



**Figure 6:** Block diagram for the heat transfer experiment – graphical source code

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 [4]. Figure 5 shows the front panels of the VI for the boiling heat transfer experimental set-up. Figure 5a shows a simple schematic diagram of the experimental setup and a brief description. By clicking on the *experiment* tab, one can switch to Fig. 5b which shows the data being measured in the experiment. This window shows the surface and near-average temperature being measured. Block diagram corresponding to this lab is shown in Figure 6.

### 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 (see Figure 7(a)). 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° panning/ 120° 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

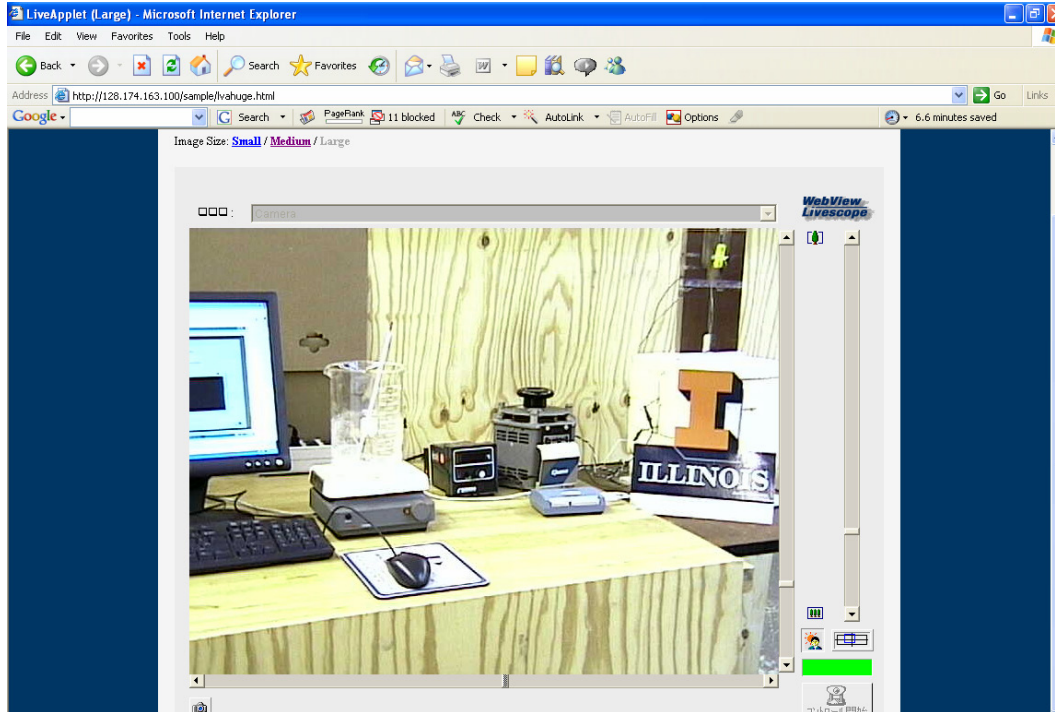
VB-EX50 Multi-Terminal Module is added (see Figure 7(b)). With this module, microphone and speakers can be connected to the camera, allowing remote monitoring of audio at the experimental site [5].



**Figure 7:** (a) Canon VB-C50i PTZ Network Camera (b) Canon multi-terminal module (VB-EX50) [5]

### 3.4 Remote Client

The remote clients only need a web browser to log into the web sites. Remote computers must have LabVIEW Run-time Engine and Java Runtime Engine (JRE) installed. These are free to download from [www.ni.com](http://www.ni.com) and [www.java.com](http://www.java.com), respectively. Figure 8 shows a network camera view as seen from 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. Conclusions**

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.

#### **Acknowledgements**

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