Chapter 17
Web-Enabled Remote Control Laboratory Using an Embedded Ethernet Microcontroller

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ABSTRACT
In this chapter, we report on the use of the TINI (Tiny InterNet Interface) microcontroller platform, DSTINIM400, as a cost effective solution to deploy feedback control laboratory experiments online. The DSTINIM400 has a built-in 10/100 Base-T Ethernet capability and provides 24 digital inputs/outputs. A TINI runtime environment, embedded in the DSTINIM400, allows developers to interact with the microcontroller like a network terminal where Java program code is downloaded and executed via the Ethernet communication protocol. The use of Java programming environment on the TINI microcontroller yields a simple interface to many Ethernet protocols allowing programmers to intuitively define a data communication link between the TINI microcontroller and a remote graphical user interface (GUI) control panel. We utilize the DSTINIM400 to interface with a variety of laboratory experiments, execute user-selectable control algorithms, and establish Internet data communication with remote GUI control panels. We provide remote GUI control panels in the form of Java applet webpages, where sensor data is presented to remote users as a plot GUI component and control system structure and parameter values are presented as binary switches, sliders, and text boxes. Finally, safety protocols are evaluated and implemented to safeguard online laboratory experiments.

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INTRODUCTION

Since the advent of the World Wide Web in the early 1990s, educators from disparate disciplines and levels have explored the use of the web to revolutionize teaching and learning. Indeed, a myriad of technological solutions have been developed and adopted for delivering courses online. Today, online courses may include static learning material rich in graphics and images; dynamic animations, simulations, and streaming videos; and computer generated quizzes and tests to promote self-directed learning and assessment. Although animation and simulation-based online instruction enriches learner experience vis-à-vis the traditional lecture-based classroom, it fails to produce satisfaction and confidence that can come only from conducting experimental studies on physical systems and achieving theoretically predicted results, particularly in engineering and science disciplines. Moreover, while simulation-based laboratory exercises may reduce monetary and time burden, they fail to deliver real-world experience of physical laboratory experiments. In this regard, effectiveness of remotely operated physical laboratories in balancing cost, real-world experience, and student learning has been examined by Corter et al., (2007) and Nickerson et al., (2007).

Although progress on the widespread availability of real-world laboratory experience through the web has been relatively slower, early efforts on this front began soon after the public introduction of the web as evidenced from a pioneering effort by Henry (1996) at the University of Tennessee at Chattanooga (UTC) to teach a control laboratory via the web. Specifically, the UTC online laboratory used a Pentium PC with a data acquisition and control board (DACB) as its hardware platform and the LabVIEW software (Bishop, 2009) as its primary control platform. This approach to online deployment of laboratory experiments was a harbinger of online laboratories developed by many other educators. For example, Esche & Chassapis (1998) developed an online laboratory, which uses the National Instrument DACB and a LabVIEW control platform, to host a series of laboratory experiments for mechanical and fluid systems. Moreover, Overstreet & Tzes (1999) reported the development of an Internet-access-based-control laboratory, which allows a remote client to compute and transmit the control signal based on the client specified reference command and the actual response transmitted by the laboratory experiment, i.e., the remote client is allowed to close the loop over the Internet.

Beginning in 2000, several authors (Apkarian & Dawes, 2000; Hahn & Spong, 2000; Wong et al., 2001) reported on the development and deployment of online laboratories which used Pentium PC with DACB as the hardware platform and the MATLAB/SIMULINK software (Hanselman & Littlefield, 2004; Dabney & Harman, 2004) as the primary control platform, and allowed remote client interaction with laboratory experiments via a Java-based GUI. Moreover, Srinivasagupta & Joseph (2003) proposed an alternative client-server concept wherein a remote client hosts the MATLAB/SIMULINK control software, which allows users full control over the control architecture, and the client-server communication takes place on the Internet to read and write sensor and control data, respectively.

Numerous efforts to deliver laboratory experience on the web are continuing to explore PC and DACB hardware platform and the LabVIEW and the MATLAB/SIMULINK software as control platform (Colak et al., 2009; Kong et al., 2009). Moreover, complimentary efforts are developing online virtual simulation laboratories as an alternative to online physical experiments (Aziz et al., 2009).

With the aforementioned efforts of the last decade, online laboratories have emerged as a valuable resource not only for the distance learners but also as a supplementary tool for the onsite students who can access laboratory experiments beyond the scheduled laboratory sessions. Un-