

Using Embedded Internet Devices in an Internet Engineering Laboratory Set-up*

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In the autumn session 2001, a new Technology strand was initiated at the University of Wollongong. As part of this added degree structure, a subject called 'World Wide Web Engineering' was introduced, which has a laboratory component focused on remote embedded Internet devices. In this laboratory, students are exposed to devices capable of monitoring digital systems remotely via the Internet. Students also learn to program these devices using special libraries available from the vendors and are given practical experience in how to compile and use this software. Survey results show that students on this new course learnt a lot about devices that can be remotely accessed and controlled via the Internet. This paper covers relevant aspects of the course development, such as setting the course objectives and creating its supporting materials. Course development costs and future improvements will also be discussed. It is shown that, in teaching this subject, a strong commitment to the use of real Internet-embedded devices enhances students' learning, instils the concept of self-learning and promotes the idea of logical deduction and team effort.

INTRODUCTION

THE SCHOOL OF Electrical, Computer and Telecommunications Engineering at the University of Wollongong has introduced a new subject called 'WWW Engineering' for its Bachelor of Internet Studies and Technology (BIST) degree. This subject includes a practical component in the BIST curriculum. The first six weeks of the course concentrates on devices such as Dallas Semiconductors' TINI (Tiny InterNet Interface) [1] and 1-wire devices [1] (see Fig. 2 in the paper by Naghdy and Taylor in this issue for a picture of the TINI and description). This practical experience allows students to learn about different aspects of WWW engineering by studying examples such as weather satellites, remotely controlled robot arms (robotoy [2]) and 1-wire weatherstations.

The last few years have seen the introduction of Internet-connected embedded devices that promise to connect the virtual world to the real world in ways that would have been considered too expensive to pursue in the past. This change has come about through two technological developments—network-enabled languages such as Java and inexpensive (under \$US200), programmable, LAN-enabled devices such as TINI from Dallas Semiconductor. The LAN-enabled devices allow sensors to be connected to them as, for example, the 1-Wire Thermachron from Dallas Semiconductor [1]. Collected data in these systems are to be logged, processed and then transmitted to a web page via Java Servlet technology. These steps can also be accomplished through a local program that

develops an 'html' page and sends it to a web server.

REMOTELY CONTROLLED EMBEDDED INTERNET DEVICES: A CASE STUDY

As a first step in providing remotely accessible laboratory experiments for undergraduate students, devices such as Dallas Semiconductors' TINI are used as teaching tools to demonstrate various aspects of Java-based TCP/IP programming. Such laboratory experiments can be set up to control a simple motor circuit using a Servlet embedded in the TINI. A variable speed DC permanent magnet motor can be observed via a PC camera to provide visual feedback on motor direction. Feedback on motor current, temperature and speed can be provided through the use of 1-Wire iButton technology, such as the Thermachron, and simple interfacing circuitry. In 2001, a simple Java Servlet was designed by a final-year electrical engineering student to provide the set-point for speed and direction of a small DC permanent magnet motor. Fig. 1 shows a photograph of this set-up. This project will be extended to provide enhancements to future planned laboratories with remote embedded Internet features.

COURSE OBJECTIVES

The WWW Engineering course objectives include the following.

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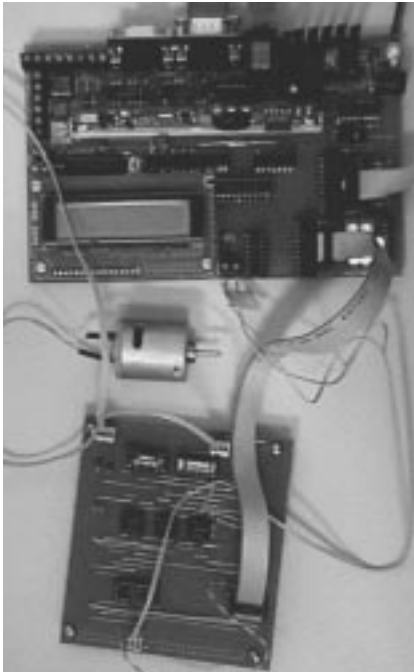


Fig. 1. Hardware set-up for remotely controlling a Permanent Magnet Motor.

- Students will be able to engineer a simple WWW communication solution.
- Students will be able to demonstrate an understanding of the systems involved in web development.
- Students will be able to demonstrate an understanding of a real-time Internet application.

The laboratory's primary objective is to illustrate the function of embedded Internet devices and to provide simple designs of such systems. The lab very much fits in with the overall objectives of the course and is an essential component of it. The methodology adopted for this purpose starts by looking at examples of embedded Internet devices. Next, individual aspects of Internet-embedded systems are examined, gradually increasing in complexity until all the components are finally drawn together in an actual implementation of an embedded-Internet device.

COURSE MAKE-UP

Six laboratories presented in this course are briefly described in Table 1. The aim of these laboratory experiments is to develop technical skills and knowledge of how to develop remote embedded Internet systems. These laboratory experiments require the use of a computer camera, 1-Wire Weatherstation, TINI, 1-wire device (such as the Thermachron) and IBM-compatible PCs. The latter provides a host computer and Java-based tools to produce the TINI executable codes.

STUDENT LEARNING PERFORMANCE AND STUDENT SURVEY

An online questionnaire was administered to obtain information from all perspectives regarding

Table 1. The six experiments and their description

Experiment Number	Description
1	Students were exposed to the various WWW engineering applications. The students were asked to visit various websites containing devices or systems. These devices typically gathered data from the local physical environment and displayed that information in some manner on a web page that could be accessed by anyone, anywhere, at anytime, such as 1-Wire Weatherstation and TINI. Also used were Windows Media Encoder, QuickCam, and freeware version of Weatherstation software from Henriksen's site [3].
2	Students were introduced to programming some simple Java examples. The TINI devices are programmed in Java, so it was necessary to ensure that the students were immersed in the experience of compiling normal Java programs. This would be used later in forming modules to communicate with Java programs and file Input/Output implemented on the TINI board. Here they did some simple examples using Swing and console output.
3	Students were introduced to investigating the FTP and Telnet servers that are provided as standard in the TINI boards. The students investigate and report on the commands that are built into TINI, especially in regard to how to download files in binary mode to the TINI devices. Once the students are familiar with all the commands, they are shown a program written for the TINI using the <code>javax.net.ServerSocket</code> class and <code>javax.net.Socket</code> class to communicate via TCP/IP with another computer.
4	This involved the use of the 1-wire Java classes from Dallas Semiconductor. The students were once again required to type in the Java program, compile it to a TINI file and then FTP it to TINI. The program was then run with a Thermochron (DS1921) connected to the 1-wire interface on the TINI board. A temperature was read back from the Thermochron and sent to the standard output device (the Telnet screen) using a <code>System.out.println()</code> method.
5	This laboratory involved setting up a simple TINI http server and then a more elaborate TINI http server that provides Java Servlets. The TINI software comes with an example application that implements a simple http server. The students were asked to compile this code and implement it on TINI, to show a simple application that TINI is capable of. The students then needed to modify the code so that it could read and report the temperature of the 1-Wire Thermachron.
6	In this final laboratory, two processes were written. One reads temperature and wind speed counter-values from a 1-Wire Weatherstation in one-minute intervals. This information was then written to a file on the TINI board called <code>Windspeed.dat</code> . This file was read by the Servlet to display data on a web browser via http.

Table 2. Student survey results

Question	Strongly Agree	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Strongly Disagree
The laboratories were relevant to the subject's content.	9	17	4	0	0	0
The laboratory in week 3 on Java Programming and ftp/telnet was relevant to the subject's content.	7	18	4	1	0	0
The laboratory in week 4 on TINI and HelloServer was relevant to the subject's content.	4	18	7	0	0	0
The laboratory in week 7 on TINI, Servlets and the Weatherstation was relevant to the subjects content.	3	17	9	0	0	0

student acceptance and their reaction to the laboratory experiments, along with overall student learning performance. Some 29 students out of 44 completed the questionnaire. The survey results, including students' written feedback, showed that the whole practice was very favourably received and useful. Survey results also indicated that the majority of students very much liked the realistic nature of the experiments conducted and the concept of self-study and investigation in the form of changing parameters in a complex Internet-based system and seeing the overall outcome in a few seconds. Moreover, because computer usage is innate to this subject, the concept of active learning proved to manifest itself quite clearly. A summary of the survey results is shown in Table 2.

The hands-on experience provided by a laboratory environment is educationally important when examining concepts related to Internet-embedded devices where the material is best illustrated by experience and practical application. Students also were interested in how the components of the application slowly came together to form a simple application. They learned how to use tools that an engineer might use to produce the simple

WWW engineering application that they developed and, as a result, took away an appreciation for what can be done on the Internet to engineer embedded WWW applications and devices.

HARDWARE AND SOFTWARE REQUIREMENTS

The hardware and software requirements for each laboratory are listed in Table 3. The main items required for development and implementation for this laboratory were 1-Wire Weatherstations, 1-Wire Thermachrons, TINI and TINI socket (E20), software for the TINI (available from Dallas Semiconductor), Java 2 (available from Sun Microsystems' website), an Internet camera (QuickCam from Logitech) and a computer workstation.

DEVELOPMENT AND IMPLEMENTATION COSTS

There were 34 experimental sets available in the laboratory. The equipment costs are \$AD 200

Table 3. Hardware and software requirements for each laboratory experiment

Experiment Number	Hardware and Software Description
1	A workstation computer running Windows 2000 equipped with web browser and Internet access. 1-Wire Weatherstation, Internet Camera, Windows Media Encoder and player (available from Microsoft), freely available software for Weatherstation from Henriksen's site [3].
2	Java 2 SDK available from Java. A workstation computer running Windows 2000, TINI and TINI socket with 9V DC 1.2 amp power supply, software for TINI from Dallas Semiconductor.
3	Java 2 SDK available from Java. A workstation computer running Windows 2000, TINI and TINI socket with 9V DC 1.2 amp power supply, software for TINI from Dallas Semiconductor.
4	Java 2 SDK available from Java. A workstation computer running Windows 2000, TINI and TINI socket with 9V DC 1.2 amp power supply, software for TINI from Dallas Semiconductor. 1-Wire Thermachron for temperature measurements.
5	Java 2 SDK available from Java. A workstation computer running Windows 2000 and a web browser, TINI and TINI socket with 9V DC 1.2 amp power supply, software for TINI from Dallas Semiconductor. 1-Wire Thermachron for temperature measurements. Software from www.smartsc.com 's TiniHttpServer.
6	Java 2 SDK available from Java. A workstation computer running Windows 2000 and a web browser, TINI and TINI socket with 9V DC 1.2 amp power supply, software for TINI from Dallas Semiconductor. 1-Wire Thermachron for temperature measurements. 1-Wire Weatherstation from Dallas Semiconductor. Software from www.smartsc.com 's TiniHttpServer.

(Australian dollars) for the TINI, \$AD50 for the Thermachron, \$AD160 for the 1-Wire Weatherstation in kit form, and about \$AD100 for the QuickCam. The school's laboratories were already equipped with computers, so their cost is not included. Only the TINIs needed to be purchased on a per PC basis, as we only needed a single 1-Wire Weatherstation, a single Thermachron and a single QuickCam in the initial implementation of the laboratory. If this laboratory were to be run remotely, it would be advisable to add extra components (for example, an Internet camera at each PC).

Future development

A follow-up to the development of the WWW Engineering subject will be a laboratory on embedded Internet devices controlling soccer robots and simple DC motors remotely. Feedback will be provided by multiplexing the single analog input available on the TINI sockets purchased for this application. It will also provide experiments that combine Bluetooth and embedded Internet devices, introducing wireless experiments as well as remotely configurable devices. It is envisaged that, using the basic design provided by the Servlets and TINI, it will be possible to remotely control a DC variable

speed motor. This follow-up laboratory is scheduled to run in August 2002.

CONCLUSION

This paper examines a newly developed laboratory set-up that deals with Internet-embedded devices and methods of remotely controlled devices via the Internet. In these experiments, students are exposed to embedded Internet devices and 1-wire devices to learn about real-time Internet applications such as logging historical weather data identifying temperature, wind speed, and wind direction. At the same time, students are exposed to simple Java programming and are given the opportunity to appreciate the advantages of Java technology for network applications. The use of the TINI boards and 1-wire devices, along with Java technology, provides students with an understanding of the existing state-of-the-art in WWW engineering and with some insight into the future use of such devices. Overall student learning performance was evaluated from all perspectives. Survey results indicated student satisfaction and high-level learning outcome. Future extensions are expected to bring about similar outcomes.

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