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## VLab: An Architecture for Remote and On-Line Basic Microprocessor Laboratory

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### Abstract

This paper presents the architecture and development of an integrated remote and on-line laboratory environment, VLab. The architecture consists of the laboratory server and client computers connected via the Internet. The operating software is developed in-house in order to keep the operating cost of the system at minimum.

On the server side, an experiment tool is connected to a server PC (Lab Server). The experiment tool includes the power controller and the result collector. Lab Server is used for communication services between the experiment tool and remote users. Two additional PCs are used as a web server and a database server.

Remote users require only a web browser to operate the experiments. A client-side program, shown as Java applet, is provided to facilitate users whereas a laboratory administrator is able to configure laboratory and manage users remotely using a web browser.

Various forms of statistical data (e.g. numbers of hex-file loading, usage time, etc.) are collected and recorded into a database for a lecturer to manage and assess his/her students. Furthermore, user authentication and resource reservation are implemented.

In order to demonstrate this architecture, VLab has been employed in basic microprocessor experiments for an undergraduate electrical engineering course at Prince of Songkla University. To some extent, the system enhances students' microprocessor programming skill provided that students have some experiences on microprocessor programming prior to using VLab.

**Keywords:** on-line laboratory, remote laboratory, virtual laboratory, microprocessor experiments.

### 1. Introduction

Remote-distance interactive learning is an important emerging educational trend. Recent technology of the Internet is an effective medium for real-time remote instruction proposes. Remote and on-line laboratory is a use of the Internet in remote-distance learning. The concept of a web-

based laboratory is not new. Only using a web browser, user can operate the laboratory equipment remotely from anywhere at anytime. The advantages in having a web-based remote laboratory are mainly:

- *different experiments:* access to experiments located at different universities,
- *flexible time-schedules:* experiments can be accessed 24 hours a day,
- *saving travel time and cost:* student's presence at the experiment location is not necessary,
- *saving equipment costs:* expensive experiments are shared among universities [2].

In this paper, we present the architecture and development of an integrated web-based laboratory environment. The system consists of the experiment section and the laboratory management. The experiment section is for students' learning and operating. The laboratory management is for the administrator and lecturer to manage and assess the laboratory. Furthermore, the in-house developed software is implemented for saving cost. The microprocessor experiments are selected to demonstrate this system.

### 2. Related Works

S.H. Chen, et al. [1] presented a method of creating a web-based remote laboratory experimentation. An oscilloscope experiment of remote laboratory in the department of Electrical Engineering, National University of Singapore, was created based on this method and announced on March 3, 1999. They developed the program by using LabVIEW for controlling instrument locally. A double client-server interface structure between WWW server and LabVIEW [5] program was proposed.

T.F. Junge and C. Schmid [2] presented a remote laboratory based on a laboratory-scale optical tracker experiment. The approach for remote experimentation incorporated software that used MATLAB/SIMULINK together with Quanser's WinCon [6] real-time system to perform the experiments. Web-based components were used to support the user interface by animation of plant models in virtual reality. An

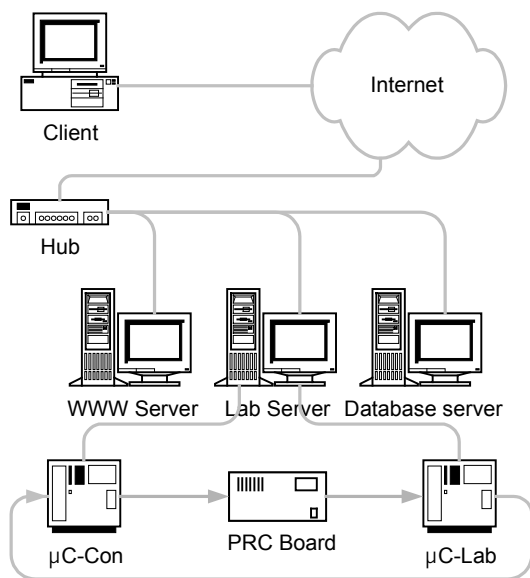


Figure 1: VLab Hardware Architecture

evaluation form has been elaborated and given to students of control engineering to judge the quality of this remote laboratory experiment. Based on the feedback received, an overall positive resonance could be noticed. Since April 2000, it has been used in the control courses of the German open university Fern Universitat Hagen.

H. Shen, et al. [3] reported on an interactive on-line web-based laboratory for remote education called Automated Internet Measurement Laboratory (AIM-Lab). It uses the Java language for the client and Visual C++ for the server. Their approach was based on developed software packages and commercial measurement equipment. They describe an application of remote experiments based on semiconductor device characterization.

G. Choy, et al. [4] presented a remote mechanical engineering laboratory. The experiment involved concurrent flow of air and water in a transparent tube of rectangular cross-section. They used a web camera to focus the flow pattern. The remote operator could view and control the experiment using a Netscape browser. The report did not describe the architecture of this remote experiment system.

Our VLab and AIM-Lab are similar architecture. H. Shen, et al. presented their architecture based on measurement laboratory. It only measured electrical conductivity of a group of devices, including a set of complementary metal oxide semiconductor (CMOS) devices and a SiC light emitting diode (LED), and displayed the experiment result. But VLab

implements more complicated and interactive laboratory. The basic microprocessor experiments are employed this architecture. User can generate source code and compile it. Then they can load the compiled file (hex file) to the microcontroller board, run program, and monitor the result.

Previously, the architecture of basic microprocessor experiments consists of a PC and a microcontroller board, which are connected via the RS232 port. We used a VT-100 terminal emulator program as a console to communicate with the microcontroller firmware, Paulmon2. We edited microcontroller operating source code using a DOS editor program, EDIT, and compiled it with a C compiler for MCS51 microcontroller. These caused students to operate the experiments in the laboratory only at daytime. Furthermore, the careless users might damage the microcontroller boards in these hands-on experiments.

### 3. Implementation

#### 3.1 Hardware

The hardware architecture consists of one client, three servers, and the experiment set. We use a PC as a client, which connects to the servers via the Internet. Three servers consist of a WWW server, a lab server and a database server, which are all connected in the same local area network.

The WWW server is assigned for VLab's WWW files to client users. A user must access to the VLab web site before operating the experiments. The lab server is allocated to communication between the experiment set and client-side program and monitoring the communication status. The database server is provided to service data from database to the other two servers as their requirements.

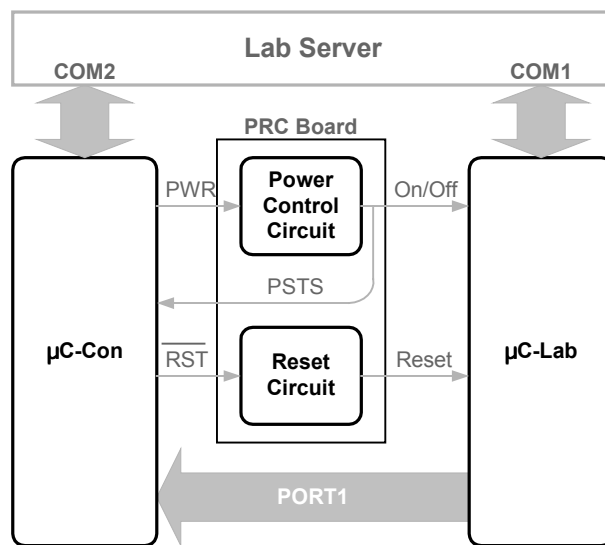


Figure 2: The Experiment Set

The experiment set consists of two microcontroller boards,  $\mu$ C-Lab and  $\mu$ C-Con, and a power and reset control circuit board, PRC Board. Two microcontroller boards are connected to the lab server via COM1 and COM2 respectively.

The  $\mu$ C-Lab is a microcontroller board that communicates with the client users indirectly via the lab server. It is provided for client user to run the experiments. The  $\mu$ C-Con is a microcontroller board that receives the commands from the lab server to control the  $\mu$ C-Lab's power on/off switch and reset switch and detects the  $\mu$ C-Lab's power status. It also collects the  $\mu$ C-Lab's port1 data. The PRC Board consists of power control circuit and reset control circuit. These circuits work under the control signals from the  $\mu$ C-Con.

When the lab server sends "power on" command to  $\mu$ C-Con, the PWR signal will be logic "1" and then the power control circuit will supply power to the  $\mu$ C-Lab. In contrary way, when  $\mu$ C-Con receives "power off" command from the lab server, the PWR signal will be logic "0" and then the power control circuit will cut off the power. PSTS is the power status signal, which will be sent back the  $\mu$ C-Lab's power status (On or Off) to the lab server. If the RST signal becomes logic "0", the reset circuit will switch to reset the  $\mu$ C-Lab for a few milliseconds. Meanwhile, the  $\mu$ C-Con will detect the  $\mu$ C-Lab's port1 signals and redirect them to the lab server, the lab server will then send these signals to the client-side program.

### 3.2 Software

Software architecture consists of two client-side programs, three server-side programs, and one server-side firmware.

Two Java applets are provided for client user to utilize the experiments. One is for communicating with  $\mu$ C-Lab as a console, VLab Console. The other is for source codes editing and compiling, Program Editor.

VLab Console is a VT-100 terminal emulator that is compatible with the  $\mu$ C-Lab firmware. This program allow user to operate the experiments, control power on/off switch, control reset switch and load hex files. The  $\mu$ C-Lab's port1 data are also displayed on the program's screen as the ASCII, binary, hexadecimal, and decimal formats.

Program Editor is an editor program with the commands to call the C compiler and Assembler. It facilitates user to edit microcontroller-controlled source code and shows compiling or assembling result and/or errors.

Server-side software consists of a lab service program, a WWW service program, and a database service program.

A Visual Basic application, VLab Server, is developed for the laboratory services. The VLab Server communicates with the two client-side programs. On the server side, the VLab Server communicates with the experiment set, monitors the laboratory status. It also collects and records various forms of statistical data. On the client side, it serves user to operate the experiments.

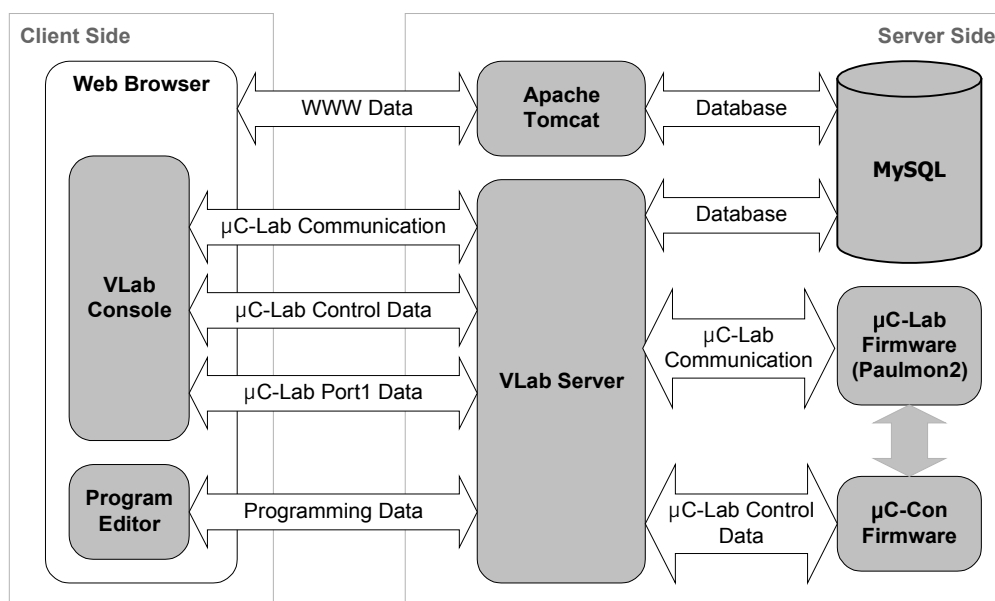


Figure 3: VLab Software Architecture

Our web site is developed using the Java Server Page (JSP) technology [7]. The Apache Tomcat 4 [8] is chosen as the WWW service since it has capability in implementation of the JSP and includes many additional features that make it a useful platform for developing and deploying web applications and web services [8].

We choose MySQL [9] as the database management software. MySQL delivers a fast, multi-threaded, multi-user, and robust SQL (Structured Query Language) database server. MySQL Server is intended for mission-critical, heavy-load production systems as well as for embedding into mass-deployed software.

There are no costs for Apache Tomcat and MySQL because they are free.

The firmware is developed to service the  $\mu$ C-Lab's power on/off and reset switches controlling and to detect the  $\mu$ C-Lab's port1 values. We burned it into the flash memory of the  $\mu$ C-Con.

### 3.3 Management System

For security reasons, users must be authenticated before accessing the web site. Furthermore, the resource reservation is provided for users to do their experiments with assigned time quota.

We provide the web-based management system to facilitate the administrator. This system consists of users and laboratory management. VLab allows the administrator to:

- add, edit, and delete user's data from the user lists,
- add, edit, and delete the laboratory topics,
- change experiment's name,
- add, edit, or delete experiment's configurations.

Besides providing the administrator tools some of statistical data are collected, i.e. user's login time, user's usage time, and user's numbers of hex-file loading, for assessing students. These data are also recorded into the database.

### 4. Test Results

A group of undergraduate electrical engineering students at Prince of Songkla University tested VLab in December 2002 and September 2003. They preferred to take VLab instead of the previous system because of the flexibility and facilities. The VLab assists their microprocessor programming skill providing that they should have some experiences on microprocessor programming before using VLab. Moreover, the damaging rate of the microcontroller board is decreased significantly.

### 5. Discussion and Further Improvement

Due to limited time of this work, some experiments in microprocessor laboratory are not supported since they require additional devices/instruments, such as LCDs, oscilloscopes, keypads, and stepping motors.

To cover all of the experiments, the following conditions should be met:

*In LCD experiment, we may:*

- connect the LCD module to the  $\mu$ C-Lab's LCD port and use a web camera to view the real-time result of LCD display, or
- capture the  $\mu$ C-Lab's LCD data and commands and then send them to the client-side LCD display emulator.

*In oscilloscope experiment, we may:*

- use an oscilloscope to measure the signals and send the data from the oscilloscope to the client-side oscilloscope emulator to display the signals' shapes, or
- use a web camera to view the real-time oscilloscope's display.

*In keypad experiment, we may provide a client-side keypad emulator program and then display the result in VLab Console.*

*In stepping motor experiment, we may:*

- connect the motor control bus with the  $\mu$ C-Lab's I/O port and use a web camera to focus the result, or
- connect the  $\mu$ C-Lab's I/O port with the encoder (either software or hardware) and detect the stepping motor control signal, then send it to the stepping motor emulator that is on client side.

The conditions above are either advantage in low cost or saving working time. So the conditions to be used in the experiments depend upon the administrator, the lecturer and/or users.

Furthermore, to save cost, we can use only one PC functions as a WWW server, a lab server and a database server instead.

### 6. Conclusions

This contribution presents the architecture and development of a remote and on-line web-based laboratory environment for undergraduate electrical engineering students at Prince of Songkla University. The client user can operate the experiments using a web browser. All of the operations occur on server side.

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