Chapter 2

E-LABORATORY ARCHITECTURE

E-laboratory is developed as a combination of virtual laboratory and remote laboratory. It is mean that E-laboratory equipped with simulations and real experiments, as stated in 1.2. Physically, as a remote laboratory, it consists of many conventional experiments, that are regular experiments conducted inside the laboratory. Three plants, namely rotary flexible link, belt conveyor and rotary inverted pendulum, are used as the experiment platform. They are arranged into a system which makes them accessible via Internet. The E- laboratory system is implemented using architecture as shown in figure 2.1.
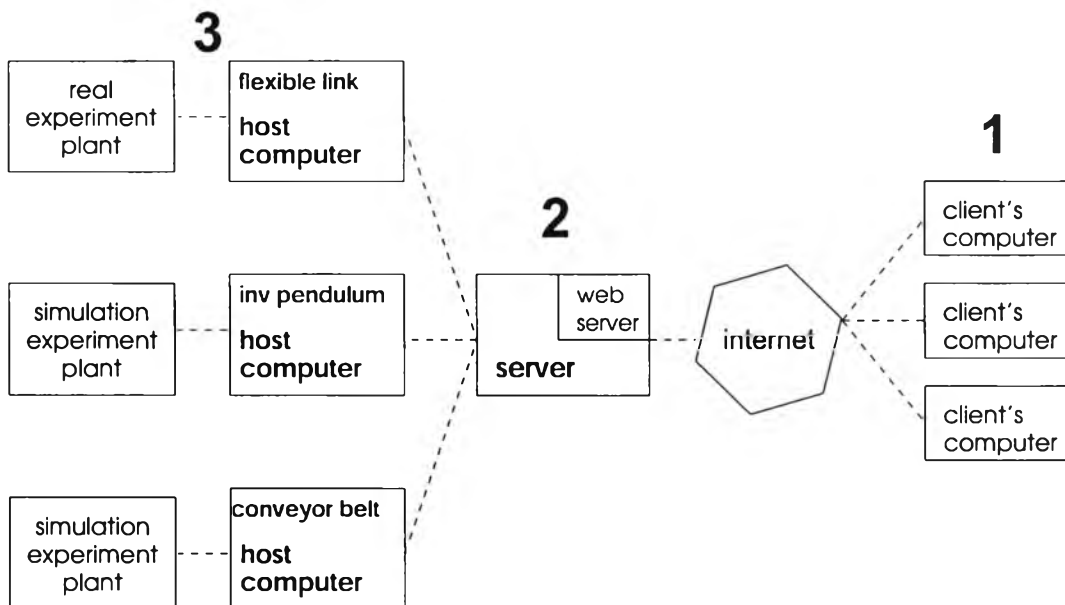

Figure 2.1: E-laboratory architecture.

From that figure, we can observe that there exist three main components of system. They are as follows:

1. Clients.

   Clients are computers which request connection, access and data from experiments through the server. Only one client can control the experiment at a time.

2. Server.

   Online laboratory server provides Web server service to run the homepage.

3. Host Computer.

   A host computer is a computer which is connected directly to the plant. It is able to access or control the behavior of the plant. In this design, the host computer is combined with a server.

2.1 Hardware

Physically a laboratory consist of plants and controller and other suporting devices. Of course, as Internet-based laboratory, network infrastructurs also unavoidably should be provided. Three plants that will be used as the platform in our application. As initial development of our system, we just connected to one experiment plant, that is rotary flexible link. Two other platforms are developed based on simulation. Their constructions are explained as follows.
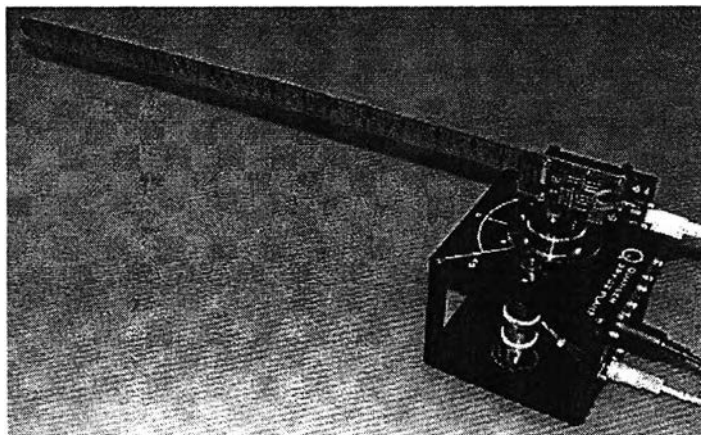
2.1.1 Flexible Link

Figure 2.2: Physical appearance of flexible link.

The apparatus (SRV-02) used for this project is supplied by Quanser. The rotary flexible link system consists of a strain gage which is mounted at the clamped end of a thin stainless steel flexible link. The experiment output is an analog signal proportional to the deflection of the link. The system is designed to mount on a Quanser rotary servo plant, resulting in a horizontally rotating flexible link to perform flexible link control experiments.

Computer

Motor Drive

Flexible Link

PLANT

A/D D/A Card

Encoder (measures the angle)
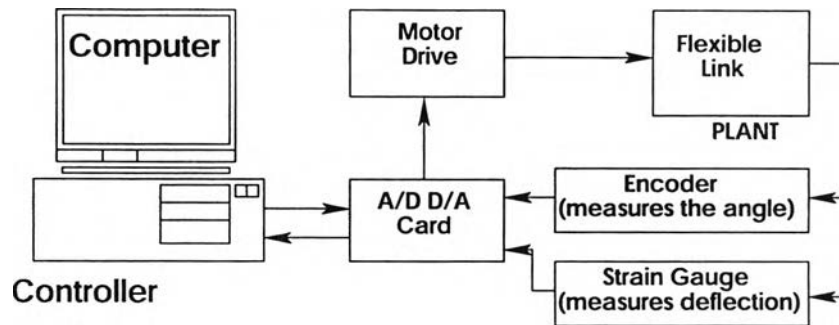
Strain Gauge (measures deflection)

Controller

Figure 2.3: Flexible link hardware structure.

The objective of this experiment is to control the position of the arm in the presence of vibration. Figure 2.3 shows the structure of rotary flexible link plant closed-loop system. For more information about this plant, in the Web page, we provide special link contain every information about the plant such as the description, system specification, mathematical model and dynamics equation. To get comprehensive explanation we can obtain the user manual from Quanser, www.quanser.com for article SRV02-series [13].

This system is similar in nature to the control problems encountered in large light space structures where the weight constraint result in flexible structures that must be controlled using feedback techniques. A DC motor rotates a flexible link from one end in the horizontal plane. The motor end of the link is instrumented with a strain gage that can detect the deflection of the tip. The rotary flexible link is an ideal instrument intended to model a flexible link on a robot or spacecraft. This experiment is also useful in the study of vibration analysis and resonance.

2.1.2 Rotary Inverted Pendulum

The second plant in the E-laboratory is rotary inverted pendulum. The rotary inverted pendulum system consists of two pendulums connected to a rotating disc which is driven by a DC motor. The control objective of this experiment is to balance the first pendulum in the upright position and to keep the other pendulum to be at rest in hanging position by regulating the rotating disc. Temporarily, we just develop simulation for this plant.

It is widely known that inverted pendulum is a hard plant to be controlled. This fact make inverted pendulum become a fascinating plants in the laboratory. Its have some instability which prevents them to work properly on their own. To apply inverted pendulum on a remote laboratory experiment is hard as we have to cope with the swing up problem. We try to develop the simulation used here to represent the real plant in linearized condition.
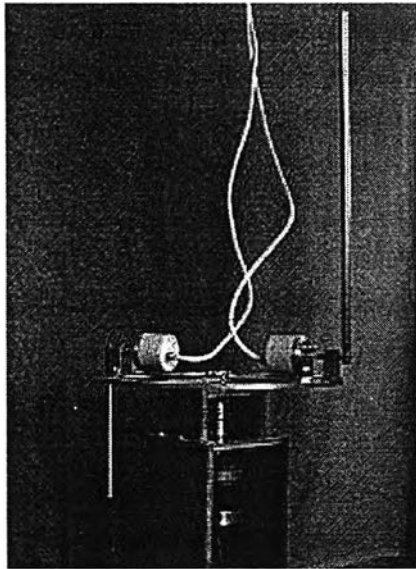
Figure 2.4: Physical appearance of rotary inverted pendulum.

2.1.3 Belt Conveyor

The third plant is belt conveyor system. This system consists of the belt lying on the iron plate with two shafts at the end. A DC motor is used to drive the belt through the shaft. The purpose of control system on belt conveyor is to regulate the speed and position of the motor which provides a driving motion for the conveyor. The physical appearance of the belt conveyor is shown in Fig. 2.5
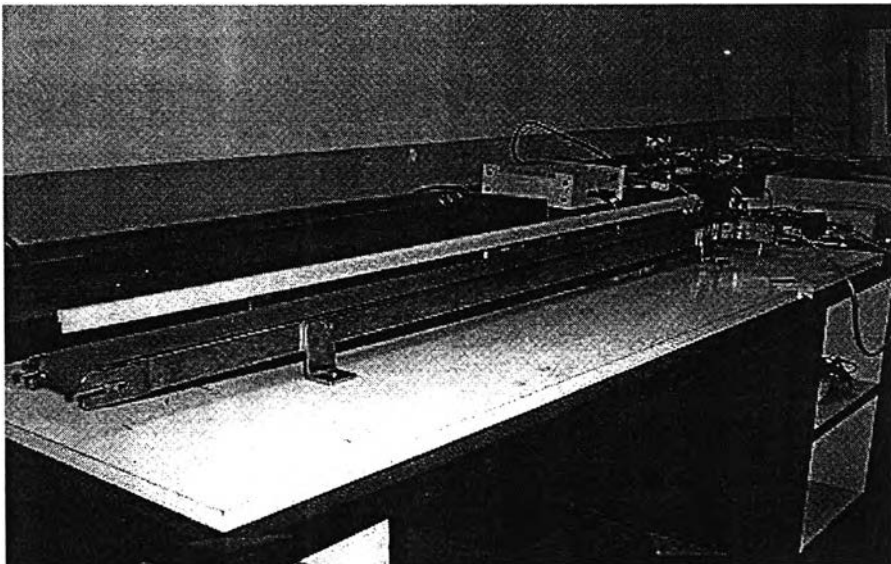

Figure 2.5: Physical appearance of belt conveyor.

Conveyor system is exploited in many industrial fields. They are used for example to transfer materials. To study this plant is beneficial for the students since they will be introduced with common real world equipment.

2.2 Software

E-laboratory brings into play some software to support its operation. To have the whole system work well, two different operating system is used to serves the client. The server employs Linux Fedora 4 to operate the network of host computers. Meanwhile, the host computers use Windows XP as its operating system, especially because of its integration with Wincon application software by Quanser. This Wincon/Quanser is used because flexible link plant is come from their development. For the browser, it is not neccessary to install specific software in the client's side since the interface that user access from the browser is purely Web-based. It does not require special condition or runtime environment. We can just use standard browser like Internet Explorer, Netscape communicator or Mozilla. The following table summarize what and where are the software that being occupied in E-laboratory system.

Table 2.1: List of software.

Element	Host	Server	Client
Operating System	Windows	Linux	OSs with common supported browser
Key component	Matlabserver	MatWeb	GUI (web-based interface)
Function	Connects and runs the experiment plants	Organizes intranet and runs the webserver	Access and request services

2.2.1 MATLAB

The MATLAB environment has been used as the core of E-laboratory system. Beside its regular function as computational, simulation and programming tool, MATLAB provide a facility that enable us publish our m-file programming or text or graphical data result. Those facilities are packed into service called as MATLAB Web Server. The components are as follows

- Matlabserver

`Matlabserver` is a multithreaded TCP/IP server which is designed to run continuously in the background as a service or as a background process on other systems. It runs the MATLAB program (M- file) specified in a hidden field named `mlmfile` contained in the HTML document. `matlabserver` invokes `matweb.m`, which in turn runs the M-file. `matlabserver` can be configured to listen on any legal TCP/IP port by editing the `matlabserver.conf` file on Windows or running `webconf` on Solaris/Linux. The number of simultaneous MATLABs is specified here.

- `Matweb`

  `Matweb` A TCP/IP client of matlabserver. This program uses the Common Gateway Interface (CGI) to extract data from HTML documents and transfer it to matlabserver.

- `Matweb.m`

  This file is used to call the M-file that you want the Web application to run.

Two configuration files are used in conjunction with the MATLAB Web Server programs:

- `Matweb.conf;` A configuration file that matweb needs for connecting to matlabserver. Applications must be listed in matweb.conf.

- `Hosts.conf;` An optional file providing additional security.

Using design in Fig 2.1, we can see that each experiment plant will be connected to their respective host computer. Between this host computer and the server, we utilize `matlabserver` and `matweb`. Figure 2.6 depicts the flow of information using Matlabserver and Matweb.

MATLAB is familiar and using this software is beneficial since students do not need to study specific programming language to design a controller. Once they create a Simulink model controller they can upload directly to the respective computer which handle the experiments. One thing that we really need to consider about the make use of Matlabserver is regarding with the access speed which quite slow. Some adjustments is still needed especially in order to acomodate the Matlabserver ability in supporting our architecture.

2.2.2 Linux Operating System

Linux is an open source operating system within the Unix family. Because of its robustness and availability, Linux has won popularity in the open source community and among commercial application developers. It was originally created by Linus Torvalds, and then the development is conducted by the assistance from developers from around the globe under
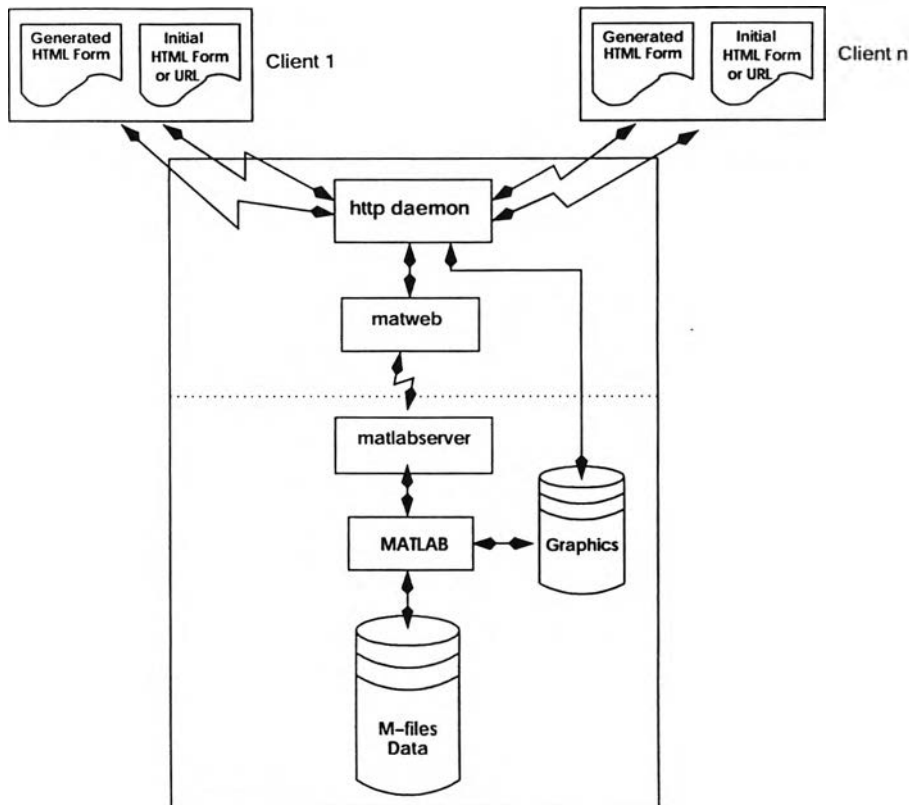
Figure 2.6: Matlabserver on the web.

license of the GNU General Public License (GPL). The GPL requires that all source code modifications and derived works also be licensed under the GPL, and is sometimes referred to as a "share and share-alike" or copyleft license.

Since then many variants of Linux are established. Individuals, loose-knit teams, and various professional organizations are develop and compile an upgraded version of Linux. We call the new variant or version of Linux as a Distribution or shortly called a distro. A description which taken from Wikipedia mentions that a Linux distribution is a Unix-like operating system comprising the Linux kernel and other assorted free software/open-source software, and possibly proprietary software. They include additional system software and application programs, as well as certain processes to install these systems on a computer. Distributions are created for different purposes, including localization, architecture support, real-time applications, and embedded systems, and many deliberately include only free software. Over 450 distributions are known available until right now. They are including famous distros such as Red Hat, SUSE, Mandriva, Ubuntu, Fedora, Debian and many more. They are freeware by default, but may be sold for the cost of packaging, bundling, and technical support.

A typical general-purpose distribution includes the Linux kernel, some GNU libraries and tools, command-line shells, the graphical X Window System and an accompanying desktop environment such as KDE or GNOME, together with thousands of application software packages, from office suites to compilers, text editors, and scientific tools.

So far, Linux has proven more popular in the server market, primarily for Web and database servers than in the desktop market. And so it is in this research, we use Linux Fedora Core 4 distribution as the operating system of our server. This server, in turn, provides support for the Web server to operate.

Fedora Core is an RPM-based Linux distribution, developed by the community- supported Fedora Project, sponsored by Red Hat. The name derives from Red Hat's characteristic fedora used in its "Shadowman" logo. The goal of The Fedora Project is to work with the Linux community to build a complete, general purpose operating system exclusively from open source software. By using this free software we hope to reduce the cost of E-laboratory application while in the same time placed our self as open source supporter.

2.2.3 Apache Web Server

The definition of web server is a computer, including software package, that provides a specific kind of service to client software running on other computers. Physically that computer is the computer that also being used as the network server. This computer manages and shares web based applications accessible anytime from any computer connected to the Internet.

There are many web server available, respect to operating system installed in the server. Internet Information Services (IIS) is a web server created by Microsoft for Windows-based Operated System Server. MacHost is a web server created by Apple for people using Machintos as their server. Software like Apache and Sun Java System Web Server can be used in many operating system since they are developed in some version with each of them specialized for special operating system.

Apache Web server is chosen to be the software that used in our system especially because its ability to support cgi-bin programming which needed by Matlabserver and Matweb. It is free-ware and suitably installed with Linux Operating System. Mourani [14] claims that Apache is the most widely used HTTP-server in the world today. It surpasses all free and commercial competitors on the market, and provides a myriad of features; more than the nearest opponent could give you on a UNIX variant. Apache claimed to be used by more than 70% web server all over the world.

2.2.4   Wincon

Wincon is a Windows application that runs Simulink models in hard real time, WinCon allows for fast implementation of real-time code generated automatically via Real-Time Workshop Runs real-time controllers on a PC under Windows 2000/XP. It is an integral part of Quanser's StudioRP system, the producer of Rotary flexible link in our experiment.

Wincon has so many key features that bring advantageous impact for control system scholastics. WinCon provides a high-performance response for rapid control prototyping (RCP) and hardware-in-theloop (HIL) testing. They claims that their real-time performance has small and predictable latencies. Wincon supports online parameter tuning via Simulink or independent of TMW software. It is also support single or multiple PC configurations, including communication via TCP/IP between Wincon client and Wincon server. Multiprocessor under Windows XP for improved sampling rates and control also supported besides it also can log data to MAT-file and M-files.