UNIVERSITI PUTRA MALAYSIA

EMBEDDED ETHERNET WEB SERVER FOR A ROBOT ARM CONTROL

TOE OO ZAW

EMBEDDED ETHERNET WEB SERVER FOR A ROBOT ARM CONTROL

By

TOE OO ZAW

Thesis Submitted to School of Graduate Studies, Universiti Putra Malaysia
in partial fulfillment of the requirements for the degree of Master of Science

October 2002

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in partial fulfillment of the requirement for the degree of Master of Science

EMBEDDED ETHERNET WEB SERVER FOR A ROBOT ARM CONTROL

By

TOE OO ZAW

October 2002

Chairman : Abdul Rahman bin Ramli, Ph.D.

Faculty : Engineering

The World Wide Web has provided a strong medium for networked computing with independent platform. As the Internet continues to grow, there will be a practical as well as economical sense to connect number of devices to the Internet. Hence, embedded web servers are needed to access, monitor, and control these devices. This work investigates the issues involved in developing an embedded web server which monitors and controls a number of devices through its re-configurable I/O ports. This thesis also provides detail discussion on the software and hardware aspects of an embedded web server. ***Site Player embedded server*** module is used as a base unit in this research. With the PC interface, embedded server module is configured with appropriate I/O control codes as well as user interface. The example application used with the embedded server module is a ***servo-drive robot arm*** which has four servo motors to control the movements of its base, arm, wrist, and grip. Further integration and greater capability of web-enable devices which are being used in factory automation and home appliances control are discussed as future works of this research.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhui keperluan untuk ijazah Master Sains

EMBEDDED ETHERNET WEB SERVER FOR A ROBOT ARM CONTROL

Oleh

TOE OO ZAW

Oktober 2002

Pengerusi: **Abdul Rahman bin Ramli, Ph.D.**

Fakulti: **Kejuruteraan**

WWW telah menyediakan sebuah media yang kukuh untuk rangkaian komputer menggunakan pelantar bebas. Dengan perkembangan Internet yang semakin pesat, adalah menjadi praktikal dan berekonomi, untuk menyambungkan beberapa perranti kepada Internet. Dengan ini, "Embedded Web Servers" diperlukan untuk mengawasi dan mengawal peranti-peranti ini. Ini melibatkan mengkaji isu-isu yang terlibat dalam menghasilkan sebuah "embedded web server" yang boleh mengawasi dan mengawal sekumpulan peranti melalui pengkalan masukan / keluaran yang boleh di konfigurasi. Tesis ini juga membincangkan secara terperinci mengenai aspek perisian dan perkakasan sebuah Embedded Web Server. Tesis ini menggunakan modul "SitePlayer® Embedded Web Server" sebagai unit asas dengan antaramuka dengan PC, modul Embedded Web Server di aturcarakan dengan kod kawalan pengkalan masukan / keluaran yang sesuai serta dengan perantaran pengguna. Contoh aplikasi yang boleh digunakan dengan modul Embedded Server ialah tangan robot berpandukan-servo yang mempunyai empat motor

servo untuk mengawal, tapak, pergerakan tangan, pergelangan tangan dan kekuatan gengaman. Perbincangan tentang integrasi dan kemampuan lanjut alatan *web-enable* yang sedang digunakan untuk otomasi kilang dan kawalan peralatan rumah disediakan sebagai kerja masa hadapan untuk kertas kerja ini.

ACKNOWLEDGMENTS

First of all, I would like to express my gratitude to my research supervisor, Dr. Abd. Rahman Ramli, for his valuable advice and guidance throughout my work. I would like to thank my fellow research students and staff at Multimedia and Imaging Systems Research Lab who provided priceless information and inputs to my research work. Dr. Borhanuddin and Dr. V. Prakash, who are the members of supervisory committee, have been very supportive and always available for their comments for my work. I also would like to thank the management of Informatics College K.L for giving me the financial assistance for my study at UPM. My wife, Molly, has helped me in all my pursuits with her love and care. Finally I would like to thank my brother, my sister, and my mother for their encouragement and having faith in me. My late father, Dr. Sein Oo, was a great source of my inspiration and I would like to dedicate this work to him.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Internet and World Wide Web

Last two decades of the 20th century saw the paradigm shift in the way computers were used. With the emergence of the Internet and Word Wide Web, the methodology of computer applications in business, industries, and academic realms has been changed dramatically.

Computers have played a major role in providing new tools and methods in various areas of work, ranging from medical diagnostic imaging to remote monitoring via satellite control to banking services.

Since the Internet has established itself as a global communication medium for information exchange, it now plays a vital role in providing efficient infrastructure for economic growth. From Mogadishu to Melbourne, the Internet plays an important part in daily life of small to large scale businesses and industries. Even though the most visible growth of Internet is in terms of the number of users and applications, much of the real growth has been in the infrastructure within the World Wide Web. Ever expanding bandwidth and ever increasing number of servers available makes the World Wide Web and the Internet accessible in every corner of the world.

The communication products and servers that enable voice and data transfer serve as the first two links in the information pipeline that has enabled the Internet to have such tremendous success. These communication products or devices are now more appropriately called "web enabled" devices.

Since more and more computers or servers are being connected to networks and the Internet, the World Wide Web continues to evolve a mere medium of transferring data to an powerful infrastructure delivering dynamic information.

1.2 The Internet Browser

Basically, the Internet browsers are user interfaces to the World Wide Web from his/her computer system. Now the applications of the Internet browsers can be extended beyond mundane tasks like searching a particular information or doing financial transaction. With the use of appropriate servers and interfaces, electronic devices can be controlled and monitored through the Internet browsers.

The Internet browsers can be used as logical interfaces for controlling and monitoring devices because they are common and familiar graphical interface, resulting in low learning for users. Further the Internet browsers can be used as a standard interface used across many platforms and applications, providing users with information gathered from numerous sources.

The web browser is now the commonly accepted standard user interface for web-based device control and monitoring systems. The web browser unique combination of widespread

use, cross platform support, open standards, and very low start-up cost has led to the downfall of proprietary command-line and graphical user interfaces. With use of a standard web browser (e.g. Microsoft® Internet Explorer®, Netscape®), web-enable devices can be accessed from any place in the world as long as there is a Internet connection.

1.3 Common Gateway Interface

The Common Gateway Interface (CGI) is a standard mechanism for interfacing external applications with information servers such as HTTP or Web servers. A plain HTML document that is retrieved from the Internet contains static information only. In other words, the information inside the plain HTML document is at constant state and does not change overtime. On the other hand, with CGI implementation, information on the web can be made dynamic which means the particular web page produces information upon the client's request, hence becomes a dynamic web page.

The rise of the Internet technologies like HTTP and their acceptance provides an efficient mechanism for the interface between the Web and an embedded system. A Web interface provides an efficient means for embedded systems data processing, control and monitoring. Since the web browsers are accepted universally as a common standard for user interface, they offer the possibility that almost any devices can be accessed remotely from almost any platform. Examples include checking stock information via mobile phone, monitoring security breach at home via a Personal Data Assistant (PDA), and sending vital status of accident victim to a specialist via hand-held computer.

Well designed graphic user interfaces offer the embedded systems manager or administrator or user the means to develop and maintain these systems economically.

1.4 Embedded Systems

Over the last decade, there has been a rapid growth in the use of microprocessor / micro-controller based products in home, office, and industrial environments. These products are considered as embedded systems since programs, controls, and I/O are all "embedded" without having direct link from computer terminals. In general, the term embedded system encompasses just about everything except desktop PCs, workstations, and mainframes.

An embedded system is one which is pre-programmed to perform a dedicated or focused range of functions as part of a larger system, usually with minimal end-user or operator intervention. The "heart" of most embedded systems are microcontrollers. In the simplest term, a microcontroller is a device which controls something. It could be controlling fuel injection system of a automobile engine or clock setting of a home VCR. Basically, a microcontroller is a computer system on a chip. It has a processing unit and peripheral components. A typical microcontroller includes CPU (central processing unit), RAM (Random Access Memory), EPROM (Erasable Programmable Read-Only-Memory), Serial and parallel I/O (input/output), timers, and interrupt controller.

Embedded systems have differentiated from desktop PC based on functionality. Generally PCs are multi-purpose machines which provide a wide spectrum of technologies to serve a broad range of application needs. On the other hand, embedded devices are fitted with

enough software to handle a specific task or application. These systems such as routers, hubs, printers, fax machines, photocopier, and home VCR to name a few. In all these systems, embedded processors/controllers implement significant functionality by executing dedicated programs autonomously with minimal user intervention. The major advantage of embedded systems over conventional control systems is cost effectiveness. Since embedded controller need minimal amount of processing power and on-chip memory, the cost is definitely lower than those full-fledge computer systems.

The embedded systems can be built with improved diagnostic features and flexibility in terms of configuration parameters. Remote monitoring and configuring of such systems is of great interest and importance. With the use of Internet, contemporary embedded systems can be monitored via dial-up connection or network connection to the system. Improving infrastructure of the Internet eliminate the need of physical proximity to the systems.

For the Web and embedded systems to interface, connectivity and interoperability options are of prime importance. The emergence of the Internet is shifting the idea of permanent function embedded devices towards more open systems offering some forms of network connectivity.

1.5 Problem Statement

Nowadays more and more devices become intelligent and there is a need to inter-connect these devices together so that they can be accessed and monitored remotely. It is estimated that by the year 2005, the number of embedded applications with the ability to connect to

the Internet will be larger than the number of PCs by a factor of 100 or more. There are varying standards where the devices communicate. For example, X10 is used in home appliances, CeBus is used in factory automation, and TCP/IP is used in the Internet. To integrate all devices together with computers, there should be a common standard of communication. Since more and more individuals and businesses are accessible to the Internet TCP/IP should become the most likely candidate for common protocol. And the Internet will be used as the common platform for all electronic devices. To achieve this each device must be web-enabled, in other words, they should be able to log onto the Internet and be accessed through the Internet. Each device will have its own 12-digit address which is unique to a particular device. Ultimately, each electronic device should become a web-server embedded to its main circuitry so that the user can access by using commonly available web browsers such as Microsoft® Internet Explorer® or Netscape®.

1.6 Objective

Since embedded web servers are the gateway to the Internet for intelligent devices, the characteristics and limitation of embedded web servers will be studied as part of the research. And possible applications of embedded web servers will also be explored and analyzed. The ultimate aim of this research is to develop a web enabled application model which can be used as an example for Embedded Ethernet Web Server application. The Embedded Ethernet Web Server used in this research will be SitePlayer® Web Server and the application will be controlling the movement of a Robot Hand remotely via the Internet.

1.7 Thesis Organization

The thesis consists of five chapters. Chapter One introduces the reader to the Internet and Embedded Systems. Chapter Two presents literature review on device interfacing via internet, web enabled devices, embedded web servers, and error tolerance issues of embedded systems.

Methodology of the research is explained by presenting conceptual design and test methods in Chapter Three. Steps involved in setting up an embedded web server as well as interfacing it with a Robot Hand are also presented in the chapter.

Results of the practical work carried out for this research is discussed in Chapter Four. As a example application of Ethernet web servers, Robot Hand is used together with SitePlayer® Ethernet Web Server. The data achieved form measurement and calibration are presented with tables in the chapter. Pros and cons of SitePlayer® is also mentioned at the end of the chapter.

Finally, conclusion and future work for the thesis are given in the final chapter. Chapter Five details the author's view on improvement for Embedded Web Server Solution as well as future applications of Embedded Ethernet Technology in Malaysian context.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Development of common interface by means of the Internet and World Wide Web has been essential for providing platform independence for computers and embedded devices alike. The Web provides a powerful tools for constructing user interfaces such as HTML, XML, or SGML. HTML (Hypertext Markup Language) offers an extensive set of interfaces primitives for use in construction of high quality interfaces whereas XML provides more flexible and adaptive features that make the web content "dynamic".

Availability and cheap or no cost of Web browsers make them best suited as web interfaces for embedded systems. Capability and accessibility of embedded systems are greatly improve by having Web browsers as Web interfaces. The device being accessible through the Web implies that there is no constraints on physical distances. A Web-based methodology eliminates the need for customized end user software and allows users to take advantage of standard browser features.

Even though the Internet provides essential platform for embedded devices to be connected online, there is still a lack of support for real-time critical communication[5]. Even in an Intranet environment that circumvents Internet bottlenecks, Internet Protocol (IP) lacks the required determinism, the capability to allocate dedicated bandwidth, essential for real-time communication. Even with such constraints, the Internet and intranets are still suitable for

performing functions such as remote diagnostics, configuration and management that do not require hard real-time behaviour. Improvements in the Internet infrastructure, such as deployment of high-performance ATM networks which can allocate dedicated bandwidth, will greatly enhance the capabilities of Internet interactions with embedded systems applications. Therefore, for practical standpoint, until or unless the Internet can provide fault-tolerant real-time communication for embedded systems, the "marriage" of the Internet and embedded devices will not last.

Currently there is an extensive work to exploit the Internet to simplify remote management of embedded devices. Each embedded will appear as a Web page with the use of HTML interface, thus enabling it to be remotely monitored, configured and controlled via common Web browsers such as Microsoft® Internet Explorer® and Netscape Navigator®. There is also an emergence of RTOS (Real-time Operating System) whose vendors are currently working on an approach which makes use of Web browsers and HTML interfaces to enable embedded systems based on RTOS to manage or be managed by other Web-enabled systems[5].

This works investigates the possible solutions for embedded systems using Web browsers as interfaces to the Internet. The investigation also involves issues arises in implementing the embedded web server solutions. Critical issues such as miniaturization of coding and language streamlining are discussed in great detail.

Since the Web technology is initially developed for mere information exchange over cross platform, it is not well suited for embedded systems for a number of reasons.

Traditional Web server software, developed for high-end computer workstations and desktop PC's, requires megabytes of memory, fast processors, pre-emptive multi-tasking operating systems, and other resources not typically available in embedded real-time environments. Many embedded systems have no Operating Systems, only kilobytes of memory, very limited processing resources, and tight real-time processing constraints.

Traditional Web Server software are not designed to handle dynamic data. Web servers are primarily designed to serve static information. Web pages represented by files of static data on a disk. Only a small portion of the Web content on the Internet represents interactive user interfaces, although a few examples exist in search engines and forms used to accept credit card information for on-line order processing. On contrary almost all the Web content in embedded systems graphical interfaces must be dynamic and interactive. Web pages served by an embedded system must be able to provide the end-user with information about the current state of the device such as networking statistics, current configuration and results of the equipment under test.

Embedded Web pages must also provide a mechanism that allows the end-user to configure and control the devices such as running a diagnostic or configuring a port. Although traditional Web servers do provide the capability to implement interactive user interfaces through CGI (Common Gateway Interface) and similar mechanisms, but they are simply