Proc. 2002 Australasian Conference on Robotics and Automation
Auckland, 27-29 November 2002

Internet Control Of A Domestic Robot Using A Wireless Lan

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Abstract

The control of domestic robots can be carried out in a wireless networked environment. This allows for realistic real time control that can be achieved through the declarative definition of networked components, the standardisation of the domestic home interfaces and the object-orientated approach to model development and data management. Internet communication can produce an efficient and effective control solution for domestic robot processes. This approach allows a remote user to monitor and control domestic robot processes in real time.

A modular mechatronic design approach has been applied to the development and control of a domestic robot lawnmower. The research described in this paper addresses the topics of Modular Mechatronics with the primary concern being the development of communication procedures for an Internet controlled domestic robot using a wireless local area network (WLAN).

1 Introduction

Network technologies have started to invade the home environment. Simple examples of such network technologies include telephone conversations, television broadcasts, signals from surveillance cameras, commands for controlling appliances and multimedia flow via the Internet and satellite transmissions.

It is possible for electric utility companies to remotely control and monitor the flow of electricity into individual homes. Currently home networking falls into two main categories:

- Computer interconnection, accessing the Internet, and connecting multiple PCs with peripherals for communication and entertainment.
- The control of items such as lights, appliances, climate control systems and surveillance cameras.

The best candidates for home-based networks are those with two or more computers, using inexpensive twisted pair network cables or voice-grade telephone wiring. This scheme accounts for about 17 million homes in the United States [Dutta-Roy]. Home networks must be based on standard products operable with any form of media. For mass-market appeal the networks have to be inexpensive, easy to install and the software simple to configure and operate.

A modular mechatronic Internet control system makes a significant contribution towards a simplified networked environment. The backbone of the network relies on the TCP/IP protocols for communication and connectivity. The PC and data networks are connected to the Home Server. This server controls the various peripherals in the home. This is achieved using multimedia capable wireless computer networks.

The effectiveness of a Wireless Local Area Network (WLAN) system depends on the presence of computer interconnection - accessing the Internet and connecting multiple PCs with peripherals for communication and entertainment. Domestic components are connected to a PC-based controller that connects to a host controller using a WLAN as in Figure 1. This design approach allows for the development of standardised control systems for the WLAN domestic robot.

2 Domestic Internet Control Technologies

Today's Internet technology provide for the development of integrated network environments for the diversified applications of different domestic home environments. To be successful in real-world applications, Internet controlled domestic robots require a high degree of autonomy and local intelligence to deal with the restricted bandwidth and arbitrary transmission delays of the Internet.

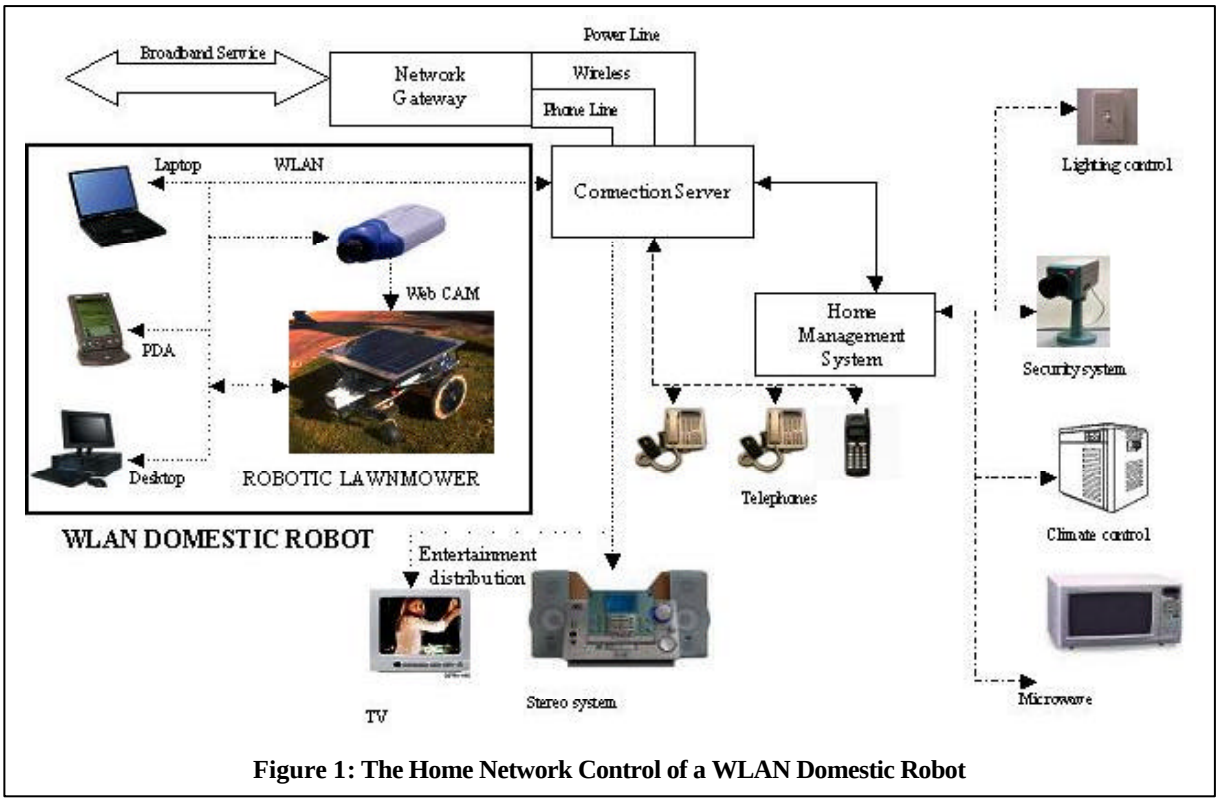

Figure 1: The Home Network Control of a WLAN Domestic Robot

With the rapid development of the Internet, more intelligent devices and systems have been developed. The notion of Internet or Web-based control for domestic robots and environments is relatively new and still in its infancy. It has captured the interest of many researchers worldwide. The Internet provides a cheap and readily available communication channel for teleoperation. There are still many problems that need to be solved before successful real-world applications can be achieved. One way to overcome these problems is to remove the closed-loop control of the human operator and provide a high degree of machine intelligence for the uncertainties in real-world applications. As researchers, it is essential to find the correct balance between human and machine interaction. An intuitive user interface is required for inexperienced people that control domestic robots over the Internet.

Communication between the Home Server and the domestic robot was achieved using wireless network adapters. The wireless Internet-based multimedia system used was based on the standard IEEE 802.11b BELKIN® Ethernet products. These include transceivers implementing a carrier radio frequency of 2.4 GHz. The maximum physical layer throughput of the system is 11 Mbits/sec. The communication working range was 50 meters.

The domestic robot must not only be controlled, but also monitored. The solution of this research problem consisted of two parts. The first part included receving information about the process being monitored. The process was naturally active during this time. The second part represented visualisation of the process on the Internet that provided actual information through the World Wide Web.

Continuous and steady image stream feedback from the domestic home environment was necessary for the Internet user to control the robotic lawnmower. The resolution of the image was adequate such that information about the state of the domestic robot could be diagnosid. The front-end imaging system of the visual feedback module consisted of three modules. These were the image sensor, the image acquisition and interface card and the computer processor. The visual feedback module consisted of two overhead cameras. These cameras were focused on the work area occupied by the robot lawnmower.

The visual feedback module used Server push technology. The live video feed was transmitted via the home server to the remote client via the use of imbedded NetMeeting technology. The communication between the robot lawnmower and Home Server was achieved using the TCP/IP communications protocol. The system used low-level control commands to instruct the robot lawnmower to perform tasks. The home server relied on the primary machine intelligence to perform the task. This control structure eliminated Internet lag problems associated with the control of machines over vast network distances. The standardisation of Mechatronic components simplified control and monitoring of the robot lawnmower. Figure 2 shows the protocol layers used during Internet information transfer.

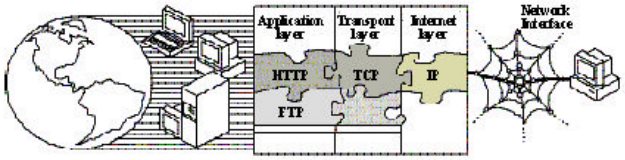

Figure 2: Internet protocols during information transfer

The domestic robot lawnmower system was a computer-based technology. The platform of the lawnmower was supplied by Husqvarna. The automated system incorporated mechatronic actuators, feedback devices and network hardware. The robotic lawnmower was controlled remotely using the supervisory control strategy. The primary controller contained the machine logic to efficiently execute the supervisory control commands from the remote Web Client.

The Home Controller received the supervisory control signals from the remote Web Client and relayed the appropriate control signals to the domestic robot. The Home Controller transmitted the control information across the entire wireless network. The domestic robot controller's set-up allowed the robot to only communicate with the Home Controller.

The transmission time performance for each command between the Home controller and domestic robot is plotted in Figure 3. This figure shows the longest transmission time interval is 8.847 milliseconds, for a 37 byte data packet at 13:00 hours. The robot lawnmower received the command to start the routine from the Home controller in less than 9 milliseconds from transmission. During off-peak times, 17:00 hours, this value dropped below 600 microseconds.

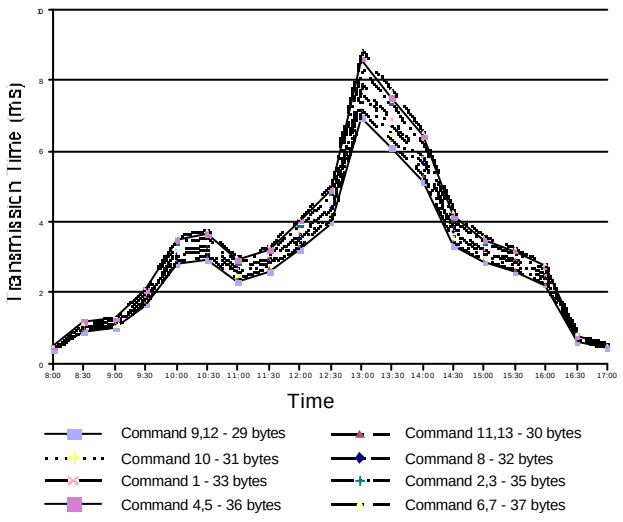

Figure 3: Graph of the transmission times between the Home Controller and the domestic robot.

If there was significant time delay in communication, instability occured and manual closed-loop control was no longer suitable. It requires a supervisory control scheme to avoid instability and makes the Internet control environment available to vast numbers of people. This opens a new range of applications for the control and monitoring of domestic automated appliances.

3 The Internet Controlled Lawnmower Program

To avoid the pitfalls of transmission delays over the Internet, the lawnmower had all its mowing functions pre-programmed into its processor unit. This allowed the lawnmower to automatically perform its range of functions which included cutting, recharging on low battery, etc. All that was required was command over the Internet. These commands instructed the robot lawnmower's processor to perform tasks such as which program to start, which area to mow, etc.

This is achieved as follows: The lawnmower's processor is continuously scanned with a simple text file (in this case mower.txt) at preset intervals (1 second, for example). Depending on the value that it read in that text file, the mower then performed the appropriate pre-programmed function.

The Internet web server also had full read-write access to this text file over the WLAN. A control web page resided on the web server that was accessible over the Internet. This was an ASP page which included the embedded web cam pictures showing a live feed of the appliance in action, some control buttons and a status window. Each control button triggered a certain VB Script sequence that either read or wrote a specific value to and from the text file. The following simple ASP VB script, for example, allowed the Start control button to write the appropriate value (in this case 1) to the text file.

```
<%
   Text = request("1")

filename=server.mappath("//it012016/mower.txt")
    Set fs =
CreateObject("Scripting.FileSystemObject")
    Set writefile =
fs.OpenTextFile(filename, 2, True)
    writefile.writeline(Text)
    writefile.Close
    set writefile=nothing
    set fs=nothing
 %>
```

When the user clicked the start button, a value of 1 was written to the text file. On its next scan of the file, the mower detected the new value and therefore started the appropriate program function. A similar bit of code read

the content of the text file when the ASP page was first displayed. It then displayed the appropriate 'current status' message in the status window.

This simple method allowed all the functions included in the domestic appliance to be easily triggered over the Internet with a minimal amount of delay between the command and the reaction to the command. Figure 4 shows the robot lawnmower in operation.

Figure 4: The Robotic Lawnmower in Operation

4 Conclusion

A internet-based control system has been developed to control a domestic robot lawnmower. The control strategy has been developed as a PC-based technology using the modular mechatronic design methodology. It represents an original and meaningful contribution to the fields of Internet technologies and modular mechatronic computer integrated systems.

The robotic lawnmower Web client graphical user interface (GUI) was developed using a combination of VBScript, HTML and JAVA. The functional capabilities of the developed WLAN Internet control structure introduced a high level of flexibility for the control of domestic robots via the Internet.

5 Acknowledgments

Massey University for financial support of the research project. Industrial companies: Husqvarna, Horizon, and AB Solar for product sponsorship and support.

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