Interfacing with Manufacturing Systems in Education and Small Industry Using Microcontrollers through the World Wide Web

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Abstract

Rapid increases in the number of people using the World Wide Web have begun to change the nature of the way people and companies do business. Trends indicate that educational and work related tasks are becoming commonplace in the developed world. Technological advancements have now made monitoring and controlling manufacturing operations commercially viable. Also, with computer use and Internet browsing becoming nearly universal, the average user now has more advanced computer skills and can more easily adapt to this new technology. By embedding web servers, microcontrollers, and wireless network devices, one can easily monitor and control both small and large scale operations. The trend toward distance control via the World Wide Web is increasing in the speed of implementation in both education and industry. The goal of this work is to explore a variety of options available to effectively introduce this type of technology into the workplace and education.

Introduction

In both education and industry there is a move toward distance communication, monitoring activities, and controlling processes and operations. According to Ciardiello (2005) "Most industrial applications today are in the area of monitoring rather than control."(p. 13) [1] However, the trend of distance control appears to be growing among industries and education. Yao (2005) suggested that the recent rapid growth in use of the internet and telecommunications that industry can now effectively monitor operations from remote location from any location in the world. [2]

This work concentrates on exploring small industrial and educational communication, monitoring, and process control applications utilizing microcontrollers and board level web servers. SCADA (supervisory control and data acquisition) systems have been used in large industrial settings for decades, however these systems tend to be very complex often involving thousands or tens of thousands of data gathering connection points, a

master control computer, and an array of custom and/or standard control software. Typical SCADA systems are beyond the reach of most educational and small industrial users in terms of both cost and complexity. In a one or two semester educational setting, using microcontrollers and board level web servers to monitor and/or control a single device provides students a cost effective opportunity to study device control from the lowest level (analyzing sensor input for example) to programming interactive internet web pages. In a small industrial setting, using microcontrollers and board level web servers can provide a cost effective platform to prototype a device control system, develop a "proof of concept" project, or implement small scale assembly or production processes.

Education

Many students, especially at the graduate levels, are currently employed as teachers or in industry who feel that traditional on-campus or even distance education programs conducted through dedicated remote sites are inconvenient or even prohibitive. The barriers are normally time related, geographic, or both (Cotton, 2000). [3] Many of these potential students are not in situations that require advanced degrees or even college credit courses, so an additional incentive to participate must be provided through convenience, value added to employment, and or cost. Some may be enticed by professional development needs as a result of teacher license renewal requirements. Draves, president of the Learning Resources Network (1999) stated that, "Online learning will constitute 50% of all learning and education. The rapid rise of learning on the Internet will occur not because it is more convenient, cheaper, or faster, but because cognitive learning on the Internet is better than learning in person." (p. 7). [4] As education becomes more deeply embedded in online-based distance education, more programs will explore options that include traditional "hands-on" instruction that is integrated into this new and growing instructional format.

Small Scale Industry

From the business and industry side, some companies are hiring employees who work either part-time or full-time from their homes using the internet as a primary tool for communication and service to the employer and/or clientele. According to Kaplan-Leiserson, (2003) "A recent study by the Society for Human Resource Management found that the number of its members offering telecommuting grew from 20 to 37 percent of its total membership over the past four years. In the United Kingdom, the number of teleworkers has risen by 70 percent over the last five years, according to that country's Office of National Statistics." (p.15) [5] With recent improvements in speed, memory, and hardware/software capabilities; it has become fairly efficient to prepare capabilities for workers to operate equipment at one site from a remote site such as from home.

Some companies conduct or coordinate operations at multiple manufacturing facilities either in part or totally from central locations. A company may keep all development and

design processes housed in a single location and then electronically transfer instructions, information, monitoring communications, or even control functions from that central location. This can reduce the necessary workforce by allowing individual workers to manage operations in multiple locations instead of being required to provide staff for this function at each location. By centralizing technical control and monitoring of automated operations, small companies can reduce on-site workers or use specialized consultants who are contracted for specific technical services that other employees cannot provide. Companies are experiencing an increasing need to reduce the number of employees required for manufacturing operations to remain competitive. Automating these operations and providing a method of monitoring and control that are cost effective for smaller industrial applications can make it possible for fewer technicians to control multiple operations from one location.

A small company may have a need to monitor and/or control only certain strategic devices. Using microcontrollers and board level web servers can provide a low cost and low complexity entry point for small companies to explore the feasibility of implementing a remote device monitoring and control system.

Growth in Technology

In the past, hands-on tasks required workers or educators to be on-site to conduct or monitor activities of students or employees. With breakthroughs in technology and rapidly falling prices for hardware and software that supports remote control of equipment via the internet this past barrier has begun dissolve. It is now possible to prepare a work environment in which students or workers can effectively and independently control manufacturing operations through monitoring and controls that can be conducted in real-time via the internet or hard-wired links from distant sites. Any size operation can be prepared for this type of remote control with a dramatically reduced need for on-site monitoring from the immediate work environment. As tasks become more complex, of course, the sophistication of the equipment and software required grows, as does the costs. In an educational environment, full-scale expensive equipment may not always be necessary to teach the principles and functions of the operations of interest. In manufacturing, by expanding the capabilities of individual workers, the need for on-site workers can be reduced dramatically, which will help significantly reduce the cost of maintaining an adequate workforce.

- **Learners are increasingly seeking distance education programs**
- **Remote site monitoring is increasing in industry**
- **In the past, hands-on tasks have not adapted well to distance controls and monitoring**
- **With current technology remote control over large distances is now easily and often inexpensively accomplished**

Interfacing

The availability of inexpensive board level web servers, microcontrollers, and wireless network devices has presented both education and industry with the option of utilizing an extensive array of affordable 'web enabled' appliances and devices. Embedding a small inexpensive web server and microcontroller into an otherwise independent device or appliance is of particular interest. Web enabling many existing electronically controlled devices may be accomplished for a low cost and possibly even less cost than the original device. Web enabled devices can provide people with physical or cognitive disabilities improved status information and control capabilities that traditional device interfaces may not provide.

Web technology is in wide use today, nearly every computer user is familiar with web browsers. Familiarity with a web browser can reduce the user's initial learning curve for understanding the human interface with a device. The human interface using web technology can be similar on a variety of computer systems; PC, Apple Mac or UNIX system. A vendor can design a comprehensive human interface for a device with little concern about the type of computer system that will be employed by the user.

Many electronic devices manufactured in the last few years have a data communication port. A simple option to web enable these devices is to utilize the existing communication port on the device for data transfer. The communication ports on these devices are generally limited to the transfer of data with few, if any, device control functions available. A device can be made proactive by enabling the email option available with many embedded web servers to report an abnormal operating condition. While this option may provide only limited functionality, it can be accomplished with little or no modification to the original device.

A more advanced option for web enabling a device is to remove its physical control panel and replace its functionality with a web interface. The manufacturer would incur the initial costs of redesigning the user interface for a device in favor of enhanced functionality, and a reduction in production cost. The reduction in production costs for a device could be achieved by the removing the physical input and output components associated with the control panel on the device. For example, direct material costs would be reduced by removing visual display components used to output device information and by removing pushbuttons and switches used as function inputs to control a device. With fewer components needed for the device, resulting in a simplified design, the production costs for the device should be further reduced.

- **Costs vary depending on level of sophistication and task - Many options are not expensive**
- **Remote access to equipment permits hands-on experiences from a distance without travel**
- **Nearly any scale operation, from small lab to heavy industrial.**

Moving the device control panel functions from the physical device to a web page removes several design limitations and provides a cost effective opportunity for enhanced functionality to the device. Visual displays installed on a device are often limited in order to keep the size and cost of the device small. Using a web interface the number and type of visual displays can be increased to concurrently show device data and status. Web interface versions of device visual displays can be further enhanced by using color and graphics.

When converting devices to use web technology and internet access security for these devices may become a concern in many situations. When it is important to manage who has access to the controls or information from web enabled devices, one should explore the options available to restrict access to the device. Once the level of security needed for the system has been determined, one should consult with vendors to determine the best strategy to restrict access to information and control functions.

Special Needs

Persons with physical or cognitive disabilities are potential beneficiaries of web enabled devices by providing them increased accessibility to a variety of devices. Talking web browsers can be employed by those with visual impairments to assist with "reading" displays and labels on device controls. Individuals with physical impairments can be assisted by replacing the physical controls on a device with web browser controls. People with cognitive disabilities could be supported by web browser enhancement of a device by simplifying how information is presented or supplementing text with graphics and/or audio.

Small Scale Education Program

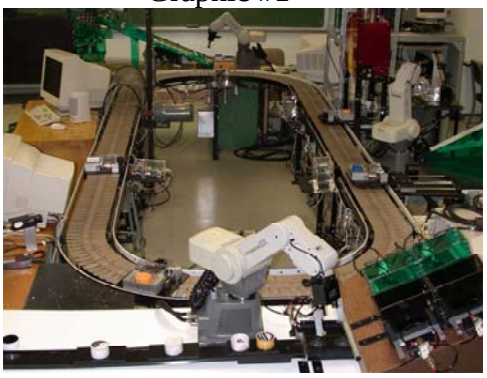
An inexpensive educational web interface program has been implemented at a Midwestern university using a student constructed and operated computer integrated manufacturing (CIM) laboratory that simulates an assembly line. A 15 foot by 6 foot oval assembly line track is the central component in the CIM laboratory with workstations positioned at several points around the outside perimeter of the assembly line track. The students developed a device known as a "smart pallet" that travels on the assembly track and communicates wirelessly with assembly line workstations for instructions required to complete product assembly. A microcontroller on the "smart pallet" coordinates infrared communication, data storage and process status displays.

This small scale simulation of an assembly line is a valuable tool for students to experience a manufacturing operation. Students learn how different devices are used to complete the operation being simulated. The small scale of the assembly line simulation has proven to be a powerful learning environment for the students. Students are required to analyze and explain the monitoring and control processes at all levels, from the most

basic devices in the system to interactive web pages. For example, when a limit switch connected to a device opens or closes (changes state), the student must be able to trace the change in the electrical signal through the physical circuitry, understand exactly how the control microcontroller interprets the change, and ultimately explain how the changes to the limit switch are displayed on the web page that is monitoring the process. Nearly any type of operation from assembly to machining operations can be simulated or developed for small scale applications by selecting appropriate microcontrollers and small scale robots or other manufacturing devices.

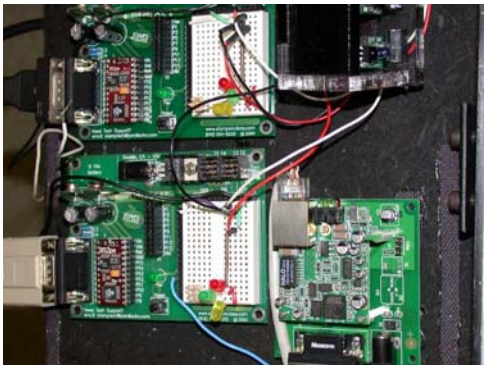
For this classroom application, students were involved with the research, design, development, construction, programming, and calibrating the system. This is an important step in the learning process for future technicians. Since the educational simulations is similar to small industrial applications, the student gain critical experience that will prepare them for being involved in the design and development activities in small industrial environments.

Graphic #1



Full assembly line view.

Graphic #2



Two microcontrollers and web server

The physical and logical beginning for the assembly process is the order entry workstation where order information is processed through a small board level web server. The web server obtains data from an order entry web page and transmits the data to the microcontroller that controls the order entry workstation. The order entry microcontroller formats the data and wirelessly transmits it to a smart pallet which is ultimately released to the manufacturing process.

To initiate new programs or simulation activities, instructors would first need to identify the learning objectives desired. Once the objectives are identified and appropriate operations selected, the instructor must determine which phases of the project each student will be involved in (research, design, development, construction, programming, calibration, etc.). Once the process to be simulated is determined, it would then be necessary to begin exploring vendors that can provide the necessary components and the costs of the components. The vendors should be consulted for specific technical details of the component being considered for the project and any additional hardware/software that may be required to support the component.

A class can be divided into development teams, each with a different task for the various phases of the research and development process. As the experience progresses, student teams would report activities and share discoveries and strategies required to overcome difficulties. For this type of activity, the preparation of each of the individual stages of the operation and the preparation of the programming required to control and monitor the simulation would normally be the primary learning objectives, with the final operation of the simulation confirming successful completion of the design. A simulation completed prior to student involvement by the instructor would address potentially intricate procedural problems prior to introducing novice learners to complex component functions and operational control of working units. Small scale equipment created using standard components can be easily adapted to a wide variety of uses, so they can be used to provide a variety of valuable experiences.

Resources

The World Wide Web is an excellent resource to locate vendors providing products to expedited interfacing controls and monitoring devices with manufacturing and production equipment through the Internet. The table below provides a few of the possible vendors and the price range for some of the items of greatest interest and application for the purposes discussed in this article. These are primarily for smaller applications and do not include heavy industrial applications. A thorough Internet search will reveal many more service, material, and equipment providers that serve a wide variety of needs and applications.

After reviewing several board level web servers the Lantronix® Micro100™ was selected for this project. Lantronix® was an established company, they provided good documentation for the product, and the Micro100 was within the $150 budget limit. Additionally, the Micro100 had good network protocol and very useful diagnostic LEDs.

The microcontroller components for this project were purchased from Parallax, Inc. The Basic Stamp 2e™ microcontroller mounted on a Board of Education™ served adequately as the interface between the web server and the devices in the CIM laboratory. A microcontroller that supports hardware interrupts will probably be used in the version of the project in order to address some timing and synchronization issues.

Vendor	Price Range
- **http://www.parallax.com**	$50-$125
- **http://www.siteplayer.com**	$30-$100
- **http://www.lantronix.com**	$70-$150
- **http://www.rabbitsemiconductor.com**	$100-$400
- **http://www.microchip.com**	$15-$90
- **http://www.mbedthis.com**	$2,500-$15,000

Conclusions and Recommendations

In the future, major growth is expected to be seen in the number of employees and students who will remotely access the tasks they are expected to execute. Geographic location will become a less critical factor in many work or educational situations, including those involving the operation and monitoring of manufacturing equipment or processes. Designers in some industrial scenarios now are not located in the involved manufacturing facility. The design work may be electronically delivered to the work site and executed without the direct intervention of those actually at the worksite other than stocking or repair and maintenance.

It is recommended that educational programs that help prepare individuals for business or industrial occupations include many experiences that include remote access to information or manual tasks. Even when an employee is working in a particular location at which where the work is being done, now and in the future, the employees often control the work from locations that are not in the immediate vicinity of the work being done. Many workers conducting production functions now do this from clean office environments while only maintenance workers are in close proximity of the equipment used. These workers often only bring stock to a particular location, do routine maintenance on equipment, or execute repairs when there are equipment failures.

Industry in the United States has been reducing the size of the unskilled workforce but increasing its dependence on highly skilled technicians. Workers with skills and experience related to automation of manufacturing operations will be in demand as the industry increases dependence on this type of specialist.

References

1. Ciardiello, Tony. (2005). “Wireless Communication for Industrial Control and Monitoring”, Computing & Control Engineering Journal. 16(2) pp. 12-13.

2. Yao, A.W.L. (2005). “Design and Implementation of Web-based Diagnosis and Management System for an FMS”, The International Journal, Advanced Manufacturing Technology, 26(11) pp.1379 – 1387.

3. Cotton, Samuel E. (2000). “Professional Development Needs Assessment for Secondary Vocational and Technical Education Teachers Related to Students with Special Needs”, Academic Quarterly Exchange. (4)2. Pp. 33-40.

4. Draves, W. A. (1999). Teaching Online, Lern Books.

5. Kaplan-Leiserson, Eva. (2002) “Office Extinction?”, T+D. 56(11). Pp 14-15.