A Generic Control Architecture for Web-Based Manufacturing

Dr. Can Saygin

Assistant Professor
Director, Integrated Systems Facility
University of Missouri – Rolla
Engineering Management Department
1870 Miner Circle
Rolla, Missouri 65409
Phone: 573 – 341 – 6358   Fax: 573 – 341 – 6567   E-mail: saygin@umr.edu
http://web.umr.edu/~saygin/

Abstract

This paper presents the design and development of a generic control architecture that enables over-the-Internet access to automated manufacturing equipment. The architecture has been developed through a series of projects that have been conducted at the Integrated Systems Facility (ISF) in the Engineering Management Department at the University of Missouri – Rolla. The projects include Web-based applications for materials management, product design and machining, robot programming, and programmable logic control programming. For each application, a prototype has been developed and implemented in the course Emgt 334 Computer Integrated Manufacturing Systems as an E-Lab Suite for various laboratory applications.

The concept presented in this paper offers a great potential for manufacturing industry by providing a means of remote monitoring, controlling, and diagnosing manufacturing systems located at different geographic locations, as well as real time data collection and analysis. Web-based manufacturing concept also provides several advantages to institutions offering distance education courses in the areas of automation and manufacturing systems. It facilitates the learning process over the Internet via a suite of Web browser based user interfaces that are linked to a physical manufacturing laboratory environment.

Introduction

The Internet technology has evolved very rapidly over the past few years and was proven to be a powerful medium for business communications. In parallel to the developments in e-commerce, the Internet is also being widely used to support various activities related to manufacturing\textsuperscript{1,2}. The advancements in manufacturing automation have led to the extensive use of computers in
the design and manufacture of products. A number of web-based manufacturing applications span from product design and development to shop floor control.

**Collaborative CAD:** Collaborative design environments enable remote designers to work together and to communicate among themselves on a common design activity. There are efforts made for manufacturing related collaborative design work shown in the literature. The main objective in collaborative CAD is to shorten the product development cycle by supporting collaboration among geographically dispersed designers.

**Collaborative CAD/CAM and Remote Machining:** Collaborative CAD/CAM systems not only allow geographically dispersed users to work together on product development by sharing knowledge and expertise in real-time but also provide remote machining (distance manufacturing) capability by downloading the machining data that have been developed in one facility to a distant facility that has the manufacturing capability.

**Web-based Manufacturing System Control:** Wang et al. present an architecture for Internet-assisted manufacturing system control. The architecture consists of an integrated computer-aided design, process planning, manufacturing, and assembly (CAD/CAPP/CAM/CAA) module interfaced with a central network server that connects to CNC machines over the Internet. The architecture allows remote users to operate CNC machines at distant locations. The authors highlighted the fact that the architecture could also be applied to flexible manufacturing systems by connecting the central network server to the FMS control computer. Therefore, results of their research might have a potential for a web-based “system” level application.

This paper presents three Web-based manufacturing system prototypes that have been developed at the Integrated Systems Facility in the Engineering Management Department at the University of Missouri-Rolla within the scope of the project entitled “WISEMAN: Web-Based Interactive System Control Environment for MANufacturing.” The goal of the project was to design a generic control architecture that enables over-the-Internet access to manufacturing functions, as well as manufacturing equipment located at remote sites. The prototypes have been designed using a generic architecture that enables portability and scalability. Due to its modular structure, it is possible to implement the architecture on various manufacturing equipment. The first prototype is a Web-based materials management system, which has been developed in 2000. The second one is a Web-based manufacturing cell control environment developed in 2001. Lastly, the third prototype is a Web-based programmable logic control environment developed in 2002.

**Web-based Materials Management**

In this application, a prototype web-based materials management software has been developed for the Small and Medium-sized Enterprises (SME) incubated at the Lemay Center for Composites Technology located in St. Louis, Missouri (http://www.lemay.umr.edu). The framework utilizes a common dynamic database to link the materials management related decisions with the factory floor. The database is managed via suite of software modules that contains administrative, purchasing, quality control, inventory, sales, and disposal operations in an integrated manner. The suite of software modules is accessed via HTML-based user interfaces.
that allow data storage and retrieval for on-site and off-site users. One of the distinctive features of this framework is that the environmental rules and regulations as well as waste management procedures are integrated with various inventory management methods in the database.

Figure 1. Overall System Architecture

The system architecture is shown in Figure 1. The MS Access-based common database resides at the lowest tier. The middle tier includes Java Web Server, Servlets, and Java Database Connectivity-Open Database Connectivity (JDBC-ODBC) driver. The user interfaces, which are located at the top layer, are linked to the web server. This architecture allows on-site and off-site users to share data even from geographically distant locations. The middle layer bridges the user interfaces with the database. Due to its web-based generic architecture, the developed framework facilitates a cooperative environment for SMEs.

Web-based Manufacturing Cell Control

The goal of this application was threefold: (1) to adapt the architecture developed for the Web-based materials management application for Web-based manufacturing system control that will allow remote users to access manufacturing equipment over the Internet and control them; (2) to develop a prototype Web-based manufacturing environment in order to implement/test the concept, and finally (3) to use the prototype environment in a distance education course. The concept offers a great potential for industry by providing a means of remote monitoring, controlling, and diagnosing manufacturing systems located at different geographic locations. Similarly, this concept provides several advantages to institutions offering distance education courses in the areas of automation and manufacturing systems. It facilitates the learning process over the Internet by providing a suite of Web browser based user interfaces that are linked to a physical manufacturing laboratory environment. Via these user interfaces, the remote users access the physical manufacturing equipment and control them as a part of their laboratory exercises without ever setting foot in the laboratory.

The system architecture supports product development, NC part programming and machining, robot programming, and manufacturing equipment control activities over the Internet. Via a
Web browser, the developed architecture allows a physical system to be remotely and interactively operated in real time by remote users across the globe.

The system essentially consists of hardware and software components that are integrated to meet the above requirements. The hardware components include a CNC milling machine, an industrial robot, part buffer, a computer serving as the cell controller, a Web-server, and network cameras. The software components consist of HTML-based interfaces, Java servlets, a database, and various manufacturing software such as AutoCAD and Mastercam. The hardware and software architectures are shown in Figures 2 and 3, respectively.

**Figure 2.** (a) Hardware Architecture  
(b) Manufacturing Cell

**Figure 3.** (a) Software Architecture  
(b) Client/Server Architecture
Web-based Programmable Logic Control Environment

In this application, the generic control architecture has been implemented to a Programmable Logic Controller (PLC) system. The system allows remote users to access and control a PLC-based table-top manufacturing system via the Internet. The system architecture is shown in Figure 4. Client computers communicate with the PLC processor over the Internet. With the help of Windows 2000 Terminal Services, the clients connect to the main server, develop their ladder logic programs, and conduct their experiments on the physical model. The physical model consists of sensors, lights, air cylinder controlled by an Allen Bradley SLC 500 microprocessor. Two network cameras provide live video.

The PLC is programmed off-line using RSLogix 500 software environment via Windows 2000 Terminal Services and then the program is compiled and downloaded to the PLC controller through an RS-232 port. The conveyor belt reflects a miniature model of the typical conveyor system in a real factory floor and it is equipped with various lights and sensors. PLC microprocessor receives the data by downloading I/O binary codes to its memory space and controls the machine devices with this data. A switched power supply is also used for adequate current at the various voltages required by the system.

Software structure of system architecture consists of RSLinx module linking devices and software applications, RSLogix 500 providing the user ladder logic programming capability, RSLogix Emulate 500 supporting the user with debug files without necessity for physical PLC’s, Windows 2000 Terminal Services supporting the user with remote access capability to the main server remotely, and Wonderware In touch 7.11 providing animation features.

Figure 4. Web-based PLC System
Conclusions

In this paper, a Web-based manufacturing system control architecture is presented. The architecture allows remote users to access automated manufacturing equipment over the Internet. The proposed architecture has been implemented on a manufacturing cell at the Integrated Systems Facility in the Engineering Management Department at the University of Missouri – Rolla and has been used as an E-Lab environment in the course Emgt 334 Computer Integrated Manufacturing Systems.

The Web-based manufacturing system control environment presented in this study is flexible and reconfigurable due to its modular software architecture that consists of Java, HTML, and Visual Basic modules. By making two modifications in the software architecture, it can easily be adapted to run different manufacturing equipment without making further changes. First, the database must be modified by the technical capability of the new manufacturing equipment. Second, a device driver must be written in Visual Basic to facilitate over-the-Internet operation.

There are several advantages of integrating a Web-based laboratory in distance education:

- Students can learn at their own pace.
- Learners are able to experience laboratory-oriented exercises from their homes or places of employment. Advances in cellular connections will enhance the flexibility of the system further by allowing mobile experimentation.
- A very active and competitive learning environment can be created to gain users’ attention and interest using current technologies, especially for adult-learners who seek flexible schedules.
- Web-based “hands-on” laboratories provide flexible access, which is very valuable for teachers and learners needing live classroom-like demonstration facilities and real-world laboratory projects.

Remote operation of a manufacturing laboratory is just one of the many applications that can be prescribed to the proposed architecture. With further investigation and improved hardware, the following applications can be performed:

- Control of remote unmanned manufacturing facility.
- Centralized monitoring and diagnostics system where one engineer serves multiple manufacturing systems from a single location.
- Collaborative research among universities and companies in the form of real-time remote data collection and analysis.

References


Acknowledgments: This research has been co-funded by the Halliburton Foundation, General Motors, and the Engineering Management Department.

Biographical Information

Dr. Can Saygin is an Assistant Professor of Engineering Management and Director of the Integrated Systems Facility at the Engineering Management Department at the University of Missouri - Rolla (UMR). He received his BS, MS, and PhD degrees in Mechanical Engineering with emphasis on manufacturing engineering from the Middle East Technical University in Turkey. After receiving his PhD degree in 1997, he joined the Mechanical, Industrial, and Manufacturing Engineering Department at the University of Toledo in Ohio as a post-doctoral research associate. In 1998, he became a visiting assistant professor at the same department. In 1999, Dr. Saygin joined the Engineering Management Department at UMR as a tenure-track assistant professor. As the author or co-author of over 35 technical papers, Dr. Saygin’s research interests include computer integrated manufacturing, web-based manufacturing system control, modeling and analysis of automated manufacturing systems, flexible manufacturing systems, and integration of process planning with scheduling. He is a member of the American Society for Engineering Management (ASEM), American Society for Engineering Education (ASEE), and Society of Manufacturing Engineers (SME).