

AC 2009-582: WEB-BASED CONTROL FOR MECHATRONICS LABORATORY EXPERIMENTS

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Web Based Control for Mechatronics Laboratory Experiments

Abstract

Mechatronics programs all over the country are gaining popularity and the student base is increasing everyday. This field of engineering brings a multi disciplinary approach to engineering education reflecting the complex nature of common products that we come across in daily life such as cell phones, airbags and myriad of appliances. In other words, mechatronic products are the fusion of mechanical devices, sensors, actuators and information systems. A classical example of a mechatronic product is an integrated robotic system. Development of web based mechatronics laboratory experiments will enhance the learning and training experience of students in understanding the concepts associated with this emerging field of technology. In this paper, a detailed account on the development of a robot and vision system based mechatronics experiments with web based control is presented.

Introduction

There is a growing trend of on-line based technology intensive course and training offerings supported with laboratory experiences ¹⁻⁵. This trend continues in the field of mechatronics and robotics & automation ⁶⁻¹⁰. Drexel's Applied Engineering Technology program deserves a special mention in developing one such laboratory for their robotics & mechatronics course ¹¹. Applied Engineering Technology program offered at the University of _____ is in the process of developing on line courses including mechatronics with web based laboratory support. This Bachelor's program in applied technology is offered totally on-line for the benefit of students from active duty military establishments and industry. This program has courses including manufacturing, CAD/CAM, robotics and mechatronics. The exercises developed in the web based laboratory will support the above mentioned courses. These laboratory exercises will serve as a means for students to gain understanding in advanced industrial automation concepts. The program is developed with an applied engineering technology focus and has a flexibility of an open laboratory. Robotics and vision system based mechatronics experiment is part of this laboratory. The Web-based system permits robotics and automation systems to communicate and share design information through the web based control ¹²⁻¹³. This provides the students with the freedom of time and space flexibility. Real-time web-controlled applications are enhancing the efficiency and capability of real-world manufacturing operations and medical services. In order to bridge the gap from academics and real life practice, the students work with real world industrial robots and equipment. Table I provides a list of experiments that a student can perform with the robotics and vision system based mechatronics laboratory.

Table I. List of Exercises with the Mechatronics laboratory

S.No.	Laboratory Exercises
1	Robot programming and application development
2	Robot sensor integration and application
3	Calibrations of vision system
4	Development of automated visual inspection system
5	E-Automatic Assembly and Color sorting using computer vision

Web-Based Mechatronics system

Primary modules of the mechatronics system in the web based laboratory are the SEIKO D-TRAN robotic system and a DVT Vision System. SEIKO D-TRAN robot is a SCARA type robot integrated with end effectors capable of handling spherical and prismatic parts. The DVT camera is used for intelligent inspection based on color detection and dimensions. In addition to this equipment, a web-cam is installed to assist the student with location, orientation and to witness the process in real time.

DVT Vision System

The DVT System uses Pixel Counting Soft Sensor that calculates the amount of pixels within a threshold range or of a given color within a given region of an image. The major purpose of this Soft Sensor is to determine the presence or absence of image features by looking at the point of interest. The intelligent inspection is based on color detection and dimensions. The DVT Vision system arrangement is show in the Figure 1.



Figure 1. DVT Vision System

The DVT vision system can essentially be described as the vision of an automated system that inspects products for defects. The DVT vision system can detect defects by comparing images and looking for the presence and/or absence of defined product parameters to determine the status of a product (such as color, measurements, codes, etc.)

The Smart Image Sensor in the DVT vision system is the hardware tool for assuring quality and, gathering data and distributing the information to the desired location for analysis.

The DVT Vision System identifies color using a software called Framework which has two applications to carry out this task. They are Blob Analysis and Pixel Count. Blob Analysis is

defined as the areas of connected pixels of similar intensity. Blob tools are Soft Sensors designed to find, count, or track blobs. The Pixel Counting Soft Sensor calculates the amount of pixels within a threshold range or of a given color within a given region of the image. The major purpose of this Soft Sensor is to determine the presence or absence of image features by looking at the area of interest.

The DVT vision system communicates with the Seiko robot with a Smart Sensor, which actuates a signal when a color is detected. This signal is the input interfaced with the robot I/O port. Once the robot I/O port has detected an input signal the program developed in SPEL is actuated and the process begins depending on the color that has been detected.

SEIKO D-TRAN Robot

Communication between the Seiko-D-Tran robot and the Vision System is established through the Interface Module. Based on the color condition, the Seiko Robot interface will send a digital signal to the robot and the necessary commands to be executed in order to complete the task. The Seiko Robot executes its assigned tasks and the procedure starts all over again making a loop for each color it detects. The complete remote laboratory setup is shown in the Figure 2.

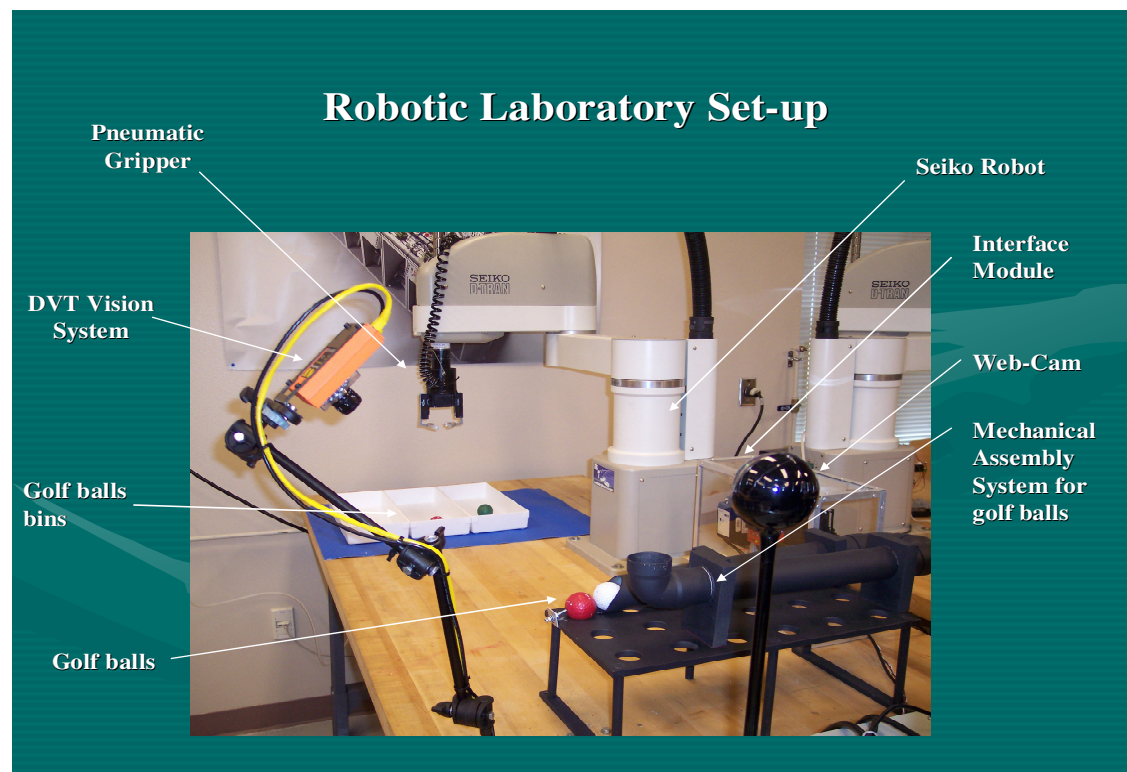


Figure 2. Robotic Laboratory Set-up

SEIKO D-TRAN Robot Program (SPEL)

Function main

```
Print " Interactive Web-Controlled Robotic Laboratory "  
Wait 3  
Integer White, Red, Green  
Mainloop:  
Green = Sw(6)  
Red = Sw(5)  
White = Sw(4)  
Whiteball:  
If White = 1 And Red = 0 And Green = 0 Then  
    ClrScr  
    Print " White Ball Has Been Detected "  
    Wait 1  
    Go P0  
    Go P1  
    On 2  
    Print " White Ball Has Been Secured "  
    Wait 1  
    Go P2  
    Print " Transferring White Ball To White Ball Bin "  
    Wait 1  
    Go P3  
    Go P4  
    Off 2  
    Print " White Ball Has Been Placed On White Ball Bin "  
    Wait 2  
    Go P3  
    ClrScr  
    GoTo Mainloop  
EndIf
```

Redball:

```
If Red = 1 And White = 0 And Green = 0 Then  
Print " Red Ball Has Been Detected "  
    Wait 1  
    Go P0  
    Go P1  
    On 2  
    Print " Red Ball Has Been Secured "  
    Wait 1  
    Go P2  
    Print " Transferring Red Ball To Red Ball Bin "  
    Wait 1  
    Go P5  
    Go P6
```

```

        Off 2
        Print " Red Ball Has Been Placed On Red Ball Bin "
        Wait 2
        Go P5
        ClrScr
        GoTo Mainloop
    EndIf
Greenball:
If Green = 1 And White = 0 And Red = 0 Then
    Print " Green Ball Has Been Detected "
    Wait 1
    Go P0
    Go P1
    On 2
    Print " Green Ball Has Been Secured "
    Wait 1
    Go P2
    Print " Transferring Green Ball To Green Ball Bin "
    Wait 1
    Go P7
    Go P8
    Off 2
    Print " Green Ball Has Been Placed On Green Ball Bin "
    Wait 2
    Go P7
    ClrScr
    GoTo Mainloop
Else GoTo Finish

EndIf
Finish:
Print " No Selected Color Was Found "
    Wait 2
    ClrScr

GoTo Mainloop

Fend

```

The communication tablet between the Robot and vision system and the corresponding interactive screens are shown in the Figure 3.

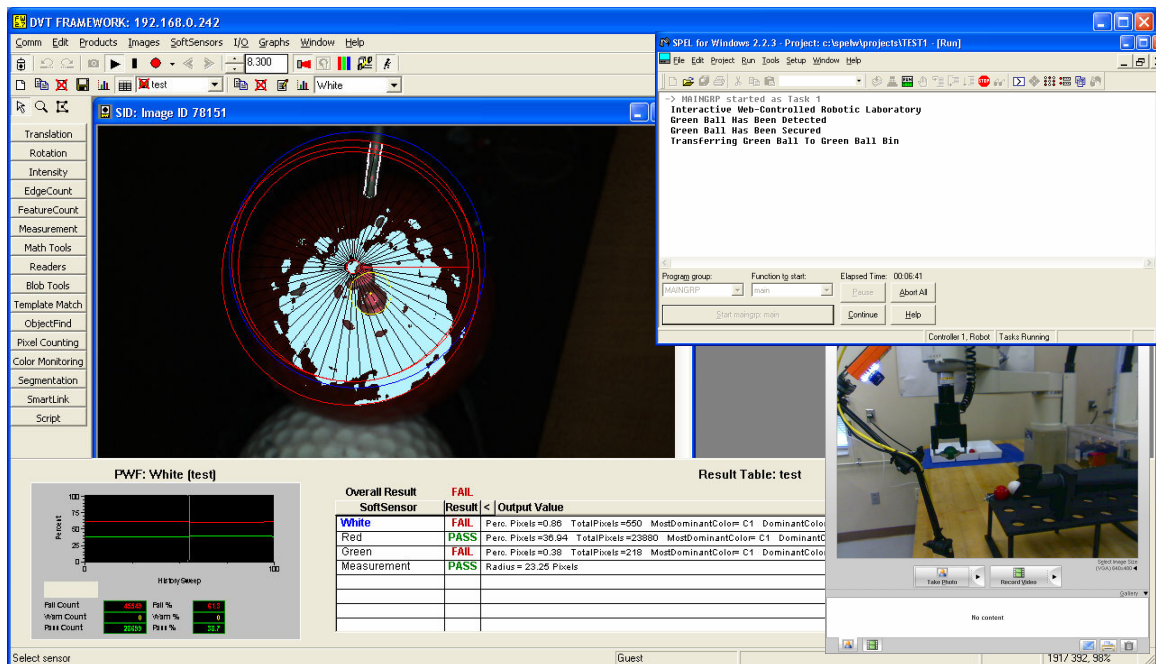


Figure 3. DVT Vision System and Seiko DTRAN Robot Program

Communication Protocol – TCP/IP

TCP/IP is a two-layer program. The higher layer, Transmission Control Protocol, manages the assembling of a message or file into smaller packets that are transmitted over the Internet and received by a TCP layer that reassembles the packets into the original message.

TCP/IP uses the client/server model of communication in which a computer user (a client) requests and is provided a service (such as sending a Web page) by another computer (a server) in the network. TCP/IP communication is primarily point-to-point, meaning each communication is from one point (or host computer) in the network to another point or host computer.

Client/server model

Client/server model is used for the user interaction, which describes the relationship between two computer programs in which one program, the client, makes a service request from another program, the server, which fulfills the request. In a network, the client/server model provides a convenient way to interconnect programs that are distributed efficiently across different locations.

System Architecture

The system architecture for the web-based Mechatronics laboratory discussed in this article is based on the client-server communication model. It simulates four levels of integration, starting with the shop floor level and ending with the enterprise level. At each level of integration,

appropriate hardware, software, networking, and communication modes for data transfer and data sharing are included. The use of many open network architectures is emphasized, in order to enable the integration of hardware from many different vendors. The hierarchical levels of the architecture (Figure 4) consist of: (1) Metrology Hardware (field sensors), (2) Control System, (3) Supervisory System and (4) Enterprise/Management Information System. These levels of integration represent sensors, metrology instruments, PLCs, computer based Data Acquisition Systems, communication networks, supervisory controllers or computers, human-machine interfaces, data base servers, web servers and various programs to provide the web-based services. The key to the success of this architecture is the ability of the database servers to support communication channels for real-time data collection, storage and access, through the OPC control applications. This enables live data exchanges between the user or Management Information System and mechatronics source that generate data on the manufacturing floor. The web server will host web services and support remote accesses to the network. The web server will also compile dynamic web data in line with different data requests received from clients and will enable interaction.

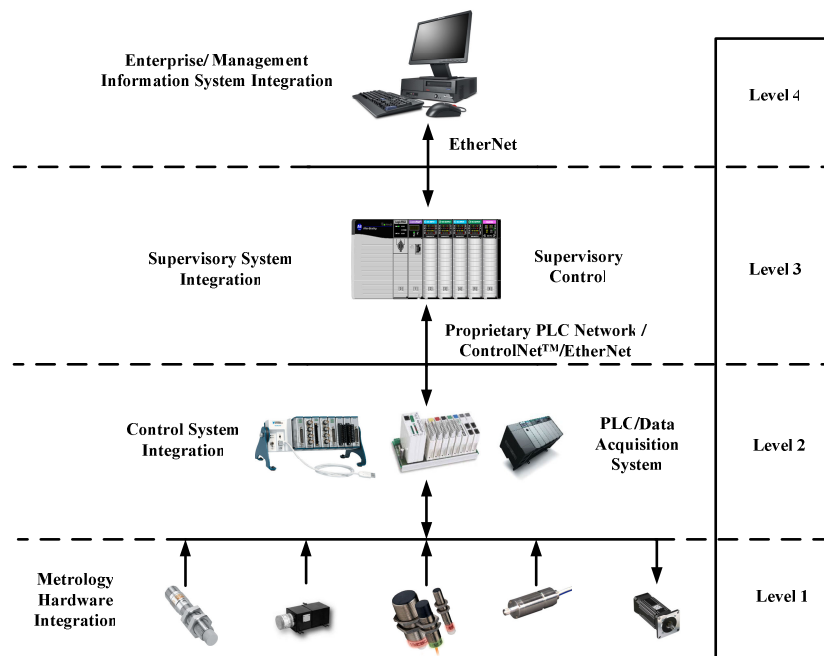


Figure 4. System Architecture for Web-based Mechatronics Laboratory

(Courtesy: Rockwell Automation Allen Bradley products)

Communication Sequence

The first step is to establish communication with the host computer which will run the programs that will control the Seiko robot and the DVT Vision System. Host authorizes the remote users to connect to the host computer and take control of it. The remote user sees the host computer screen and takes over the control and can open files or programs that he/she has permission to

access. Before remote users can connect to the host computer, the host has to set up the host-computer to allow the connections. Host must specify the connection type, what method to use to ensure that remote users have permission to access the host computer, and other session options. This information is stored in a host connection item file (.bhf), which appears as an icon in the Host's window.

The second step is to connect with the host computer via the internet. The sequence of tasks for the remote management is shown and explained in the Table II below.

Table II. Remote Management tasks.

Task	Description
Task Manager	Lets the user to view and control applications and processes that are running on the host computer. See Managing tasks remotely .
Command Prompt	Lets the users run basic DOS commands on a host computer (for example, ipconfig) and view the text-based results locally. See Running DOS commands .
Services	Lets the users view all services that are running on the host computer. The users can start or stop a service, change its startup mode, change its logon properties, and view dependencies. See Viewing services .
Edit System Files	Lets the users view and edit text-based system files and save your changes locally or on the host computer. See Viewing and editing system files .
Edit Registry	Lets the users remotely edit the system registry of a host computer over a network or modem connection. See Viewing and editing the system registry .
Event Log	Lets the users view information about application, system, and security events on the host computer and save the event log files. See Viewing the event log .
Installed Programs	Lets the users view information about the programs and software updates that are installed on the host computer and uninstall them if necessary.

Task	Description
	See <u>Viewing and uninstalling programs</u> .
Change Computer State	<p>Lets the users remotely lock, restart, or shut down a host computer or log off the user who is logged on to the host computer.</p> <p>Users can also send these commands to one or more computers out of session by using Quick Connect.</p> <p>See <u>Restarting or shutting down a host computer during a remote management session</u>.</p> <p>See <u>Locking a computer or logging off a user during a remote management session</u>.</p> <p>See <u>Sending system state commands to one or more computers</u>.</p>

Educational impact

This remote laboratory is used for the distance education courses in the applied engineering technology program. Students learn basic programming skills for robots and vision systems and perform the mechatronics exercises listed in the Table I. Work-study at the laboratory monitors the set-up for possible crashes. Students showed interest in learning programming techniques through this remote learning arrangement. At a given time, program allows a single user for download and operation. Work is underway to develop other remote controlled technology experiments for asynchronous and distance course offering of applied engineering technology programs.

Learning experiences and future development

The mechatronics laboratory was designed and developed through a series of senior design projects. This project provided the students with ample opportunities for cross disciplinary learning of advanced engineering concepts in mechatronics. The student teams that involved in the design and development of this experimental platform had students from mechanical, electronics and manufacturing engineering technology disciplines. The students that worked on the modules such as end-effectors design, electronics interface and programming distributed their work content based on their skill sets associated with their respective disciplines. The team members also could learn from each other in solving the common integration and interfacing issues with the project.

Applied Engineering technology students had the opportunity of trying out the web-based mechatronics experiments. An informal survey of students revealed the fact that most of them liked the idea of learning advanced mechatronics concepts through the distance learning method. They also understood the discipline of web-based experimentation such as the precautions that

one has to exercise in working with real life equipment from a remote location. The time delay, even though it was minimal due to the fast internet connection, will be a critical issue in some of the real world manufacturing applications involving fast moving equipment such as industrial robots and in medical field. There are several areas of the laboratory that needs improvement such as availability of multiple experiments to minimize the queue for access, integrated multi media capability for increased interface of students and experiment, increased band width for fast internet connectivity and dedicated web page service for web based experimentation. These enhancements in the web-based mechatronics experiments will be pursued as activities for future senior design projects. Improved web-based laboratories in the emerging fields of engineering and technology such as the one in mechatronics will serve well in producing trained engineers and technologists in the critical field of advanced manufacturing.

Conclusion

The paper presented the details of interfacing the DVT Vision System with the Seiko Robot as well as to implement an Interactive Web-Controlled Mechatronics Laboratory in real time. The project has helped students to envision of how this type of technology can be implemented in different equipment in the real world industry set-up. This technology is being used today not only in manufacturing but also in the medical field and in the military. However, this has several constraints, like time delay, supervision and limited bandwidth of the internet. In the future, like every new technology, with time the process will be perfected with continued research and development.

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